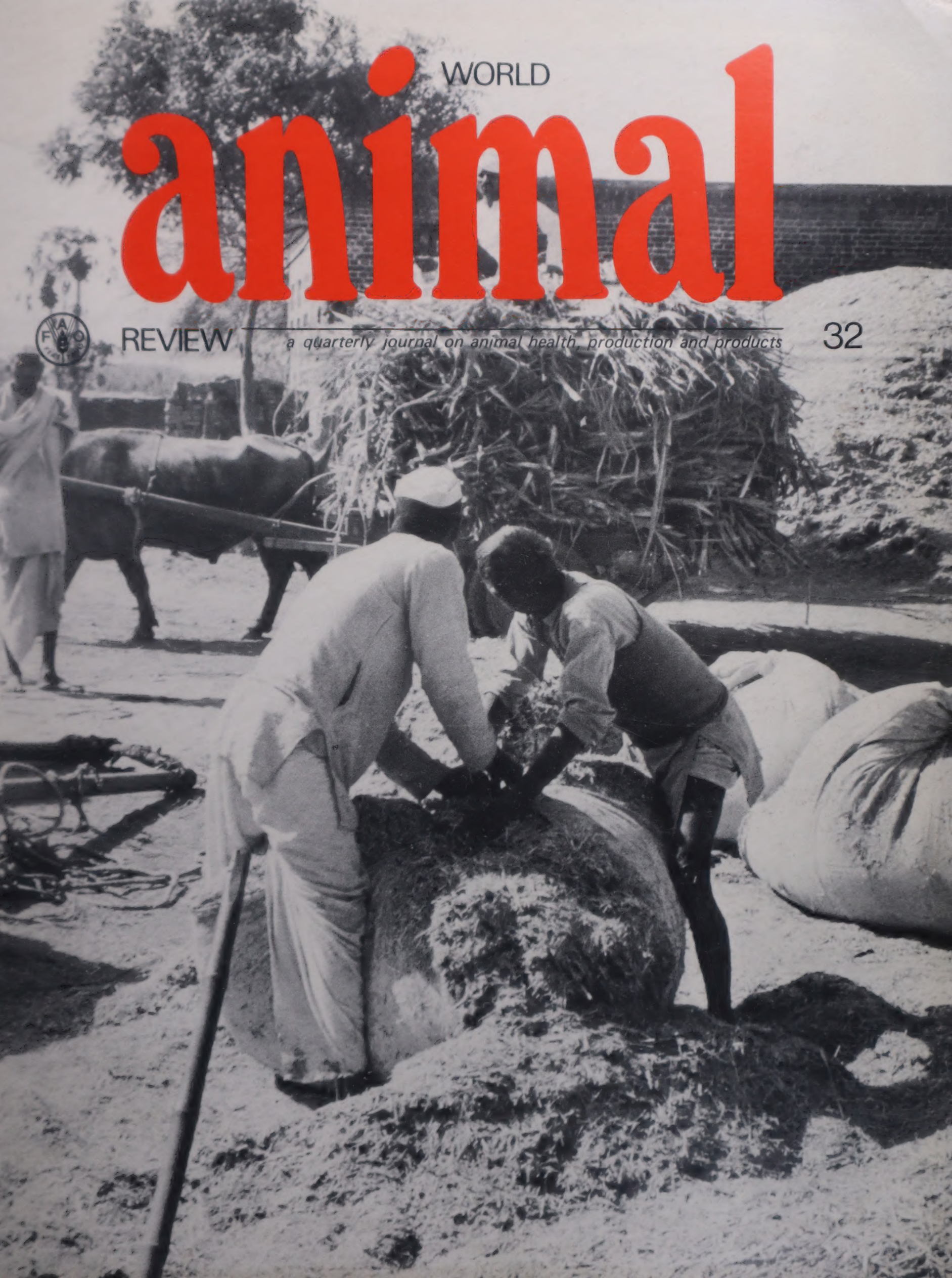
WORLD

animal

REVIEW

a quarterly journal on animal health, production and products

32



COMMENT

Feedstuffs for Animals

In developed countries there may be a need for some substitution of traditional concentrate feeds based on cereal grains fed to livestock because of factors such as the increasingly unfavourable price ratio of concentrate feeds in relation to animal products.

In the developing world, however, priority given to food production on arable land makes the outlook for animal feedstuffs extremely serious. In most of these countries the demand for animal protein is rising steadily due to increases in growth of population and incomes. Rising demand may be satisfied by higher imports of animal products and animal feedstuffs but these often lead to increasingly adverse trade imbalances. There is, therefore, an urgent need for many countries to increase their domestic production of animal products.

The developing world as a whole has vast animal resources including 70 percent of the world's cattle and buffaloes and 60 percent of its sheep, goats and pigs. These livestock need to be made more productive; improving their feeding and management is one of the quickest and surest ways of doing this.

The difficulty is that in most countries feed requirements exceed supply and, in regions such as the Near East, many countries do not have the potential for greatly increasing the production of feedstuffs.

In many developing countries livestock depend mainly on natural grazing lands under tribal or communal use. These are diminishing as the best areas are taken over for food production while fuel collection from trees, bushes and roots, overgrazing and lack of systematic management reduce the productivity of the remainder.

In other developing countries with relatively high rainfall, small holdings tend to concentrate on crops but depend on livestock for draught, for supplementing the farmers' income and for essential food items for the family. Because of the shortage of land very little fodder is grown and the livestock subsist on crop residues of low nutritive value. Although having a high degree of adaptability to local environmental conditions the low level of feeding prevents the animals from expressing what is, in any case, a relatively low genetic potential for production.

Great difficulties are involved in achieving increased animal production from the rangelands and grasslands. Only slow progress can be expected in increasing forage and feed by the development of integrated systems of crop and animal husbandry (including the use of fallow); by conserving forages by hay and silage making utilizing irrigated and rainfed forage crops; and by increasing forage production and its conservation in grassland areas or from highly productive pastures in improved, integrated crop/livestock systems. There is, therefore, an urgent need to develop new feed resources and to improve the feeding value of existing poor-quality cellulosic roughages from farm residues such as straws, stubbles, haulms, vines, sugar-beet pulp, and other agricultural by-products and from agro-industrial by-products such as slaughterhouse by-products and those from the processing of sugar, cereal grains, citrus, olives, dates, vegetables and fruits.

The feeding value and palatability of some of these by-products, especially the straws, have to be improved by appropriate chemical treatment (as by the use of alkalis) and by other treatments such as grinding and the use of steam.

Low-quality roughages such as straw, of which there are large quantities in many developing countries, can contribute to the maintenance of large numbers of animals or help to carry them through the dry season when alternative feeds are scarce. Being deficient in several nutrients they are, however, of little value when fed alone. Good results have been obtained from feeding straw with added molasses, while urea (already being produced in large quantities by some of the oil-producing countries) has been used to supplement poor-quality forages, such as straw, to compensate for their low nitrogen content. In designing large-scale projects for promoting the utilization of these feeds it will be necessary to overcome problems arising from the bulk and cost of transport of many of them.

Besides the potential of new feed resources and the scope existing for improving low-quality roughages as mentioned above, other sources of potential new feeds should be noted. These include those from the wood and cellulosic industry, from the recycling of animal and municipal wastes (e.g., poultry excreta) and from single-cell proteins.

A large amount of literature has accumulated during recent years on unconventional feeds and on by-product feeds used in suitable combination and particularly in regard to sugar cane and to sugar industry by-products.

FAO attaches the greatest importance to the whole subject and in 1976 organized a Technical Consultation on New Feed Resources, the report of which, together with a separate publication containing all the technical papers presented at the meeting.

(Continued on page 52)

WORLD
animal
REVIEW *a quarterly journal on animal health, production and products* *no. 32 - 1979*

WORLD ANIMAL REVIEW is a quarterly journal reviewing developments in animal production, animal health and animal products, with particular reference to these spheres in Asia, Africa and Latin America. It is published by the Food and Agriculture Organization of the United Nations. FAO was founded in Quebec, Canada, in October 1945, when the Member Nations agreed to work together to secure a lasting peace through freedom from want. The membership of FAO numbers 144 nations.

Director-General: Edouard Saouma

WORLD ANIMAL REVIEW [abbreviation: **Wld Anim. Rev.** (FAO)] is prepared by FAO's Animal Production and Health Division, which is one of five divisions in the Agriculture Department. The Division is subdivided into three technical services concerned with animal production, meat and milk development, and animal health.

Chairman of the Editorial Advisory Committee: H.C. Mussman (Director, Animal Production and Health Division).

Acting Technical Editor: D.E. Faulkner.

COVER: Chopped rice straw being used as animal fodder in India.

The use of nuclear techniques in improving reproductive performance of farm animals

B.M.A.O. Perera and A.S. Abeyratne

Improved reproductive performance is essential for increasing the productive efficiency of farm animals, particularly in developing countries where poor reproduction caused by factors associated with management, nutrition, climate and disease is a major constraint to economically viable livestock enterprises. Studies on the common reproductive problems under such conditions and the formulation of programmes applicable at the field level for alleviating them are, therefore, urgently required.

Research on animal reproduction is greatly facilitated by techniques for measuring hormone concentrations in blood and other body fluids. However, research is by no means the only application of these techniques. Hormone assays are becoming increasingly important tools for management and diagnosis and as methods for monitoring the response to corrective measures.

At present the methods of hormone measurement that are most sensitive, accurate and convenient in practice are those involving the use of radioisotopes. This article describes the current and potential applications of these in vitro *nuclear techniques for improving reproductive performance of farm animals, with particular emphasis on cattle and buffalo production in developing countries.*

Hormones of reproduction. The sites of production of the main hormones involved in reproduction are the brain (hypothalamus and pituitary gland), gonads (ovaries in the female and testes in the male), uterus and placenta. The activity of the gonads is stimulated by gonadotrophic hormones secreted by the anterior pituitary gland. The two main gonadotrophic hormones are luteinizing hormone (LH) and follicular stimulating hormone (FSH), both of which are glycoproteins. Their release to the bloodstream is governed by hypothalamic polypeptide hormones, termed releasing factors. The gonads, in addition to producing the ova and spermatozoa, secrete steroid hormones: chiefly oestrogens and progesterone in the female and androgens in the male. These in turn exert a regulatory influence on the release of gonadotrophins through feedback mechanisms on both the hypothalamus and the anterior pituitary (Figure 1).

In the female, oestrogens are secreted from maturing Graafian follicles in the ovary and are required for coordinating the events leading up to mating and conception. Progesterone, which is secreted by the corpus luteum (CL), is required for the maintenance of pregnancy. The consecutive presence of elevated concentrations of progesterone and oestrogens is necessary for the expression of oestrus or heat. In the male, androgens are secreted by the Leydig cells in the testis and are responsible for a variety of reproductive functions, including sexual drive or libido, formation and maturation of spermatozoa and secretion of seminal fluid. The uterus plays an important role in the regression of the CL in non-pregnant females, thereby allowing the repetition of the oestrous cycle. This luteolytic activity is now known to be mediated through the secretion of prostaglandin $F_{2\alpha}$ ($PGF_{2\alpha}$) in many species of farm animals. The pregnant female has a further endocrine organ, the placenta, that may secrete different gonadotrophins and steroids depending on the species.

Measurement of hormones. The measurement of the concentration of hormones in blood affords a convenient way of assessing the reproductive status of an individual. It should be remembered, however, that the circu-

B.M.A.O. PERERA is with the Department of Veterinary Clinical Studies of the School of Veterinary Science, University of Peradeniya, Sri Lanka. A.S. ABEYRATNE is with the Artificial Breeding Services Division of the Department of Animal Production and Health, Peradeniya, Sri Lanka.

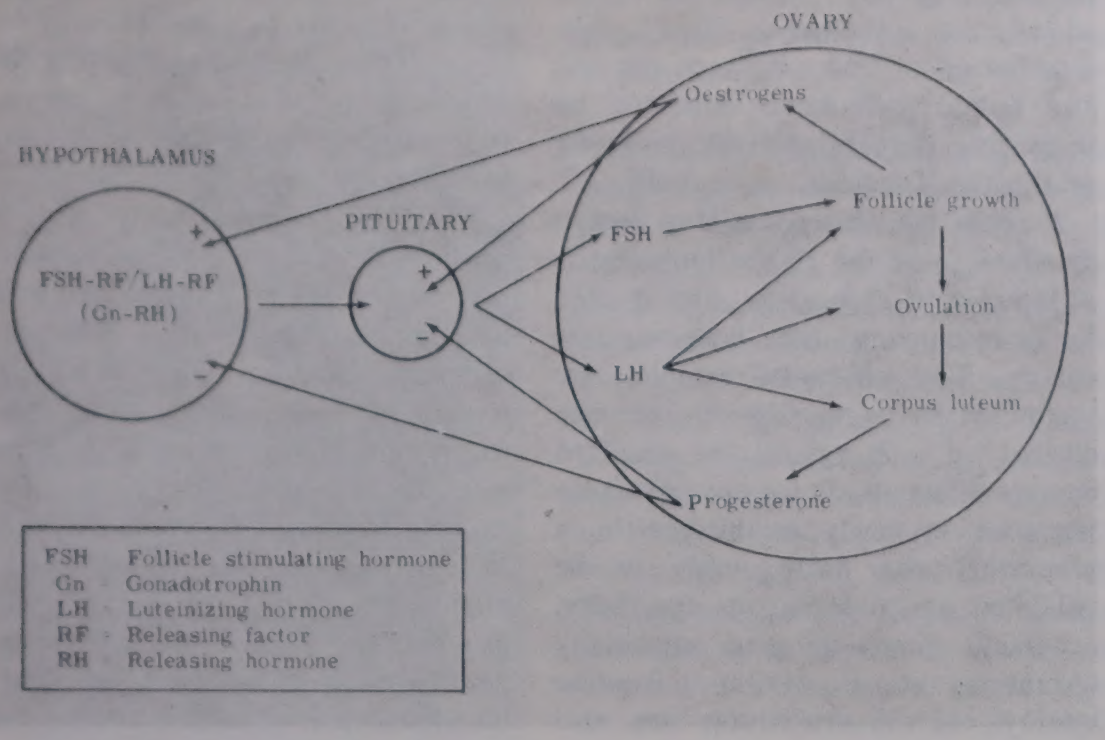


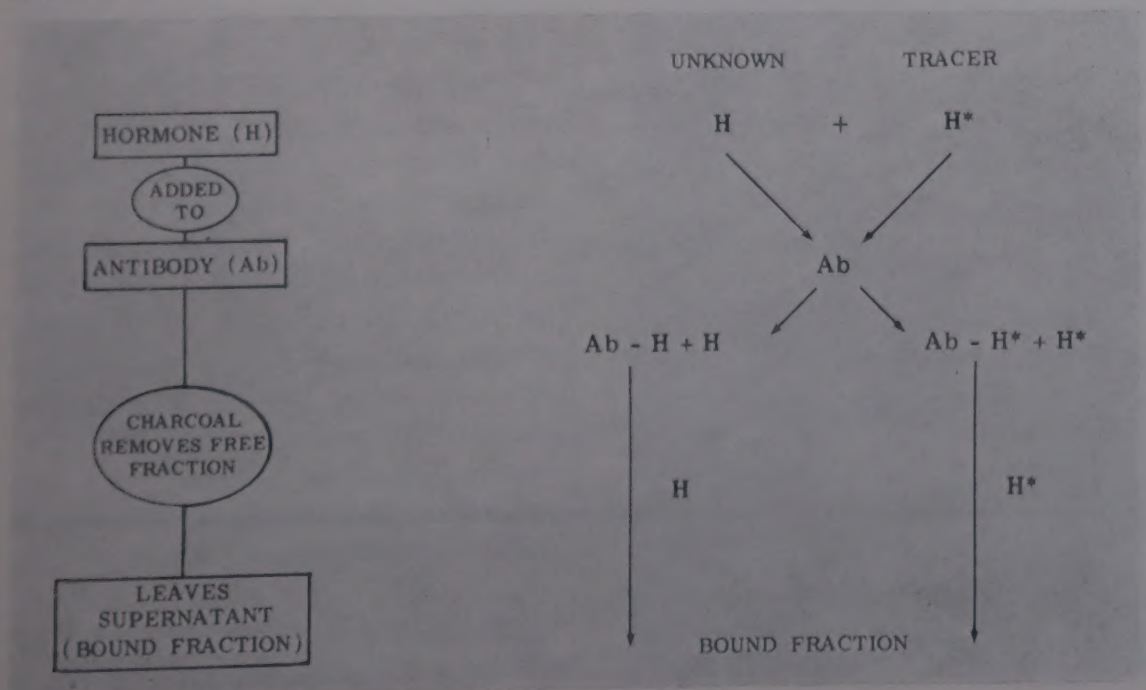
Figure 1 *Hormonal interrelationships between the hypothalamus, anterior pituitary and the ovary.*

lating level of a hormone will be influenced by many factors: the rate and pattern of secretion or release, the compartmental distribution in the body, metabolism, clearance or excretory rate, and the presence of the hormone in free or bound forms. A major obstacle to the measurement of reproductive hormones is their extremely low concentrations in peripheral blood. The majority of currently available chemical and bioassay methods are not of sufficient sensitivity to allow for their measurement in convenient volumes of blood. The use of radioisotopes, however, has facilitated the development of a group of techniques termed radioligand assays that are capable of overcoming this difficulty.

The basic principle of these assays is that the hormone to be measured competes with added radioactively labelled hormone for binding sites on different protein substances. Where the binding agent is a specific antibody raised against the hormone (antigen) the technique is termed radioimmunoassay (RIA), a term introduced by Berson and Yalow (1959). In systems where the binding agent is a selected plasma protein the technique is called competitive protein-binding assay. The commonly used, naturally occurring binding-proteins for this technique are cortisol-binding globulin for cortisol and progesterone assay and sex-steroid-binding plasma protein for testosterone assay. The methodological details of these techniques have been described by Edqvist *et al.* (1976). Systems using target-cell receptors as binding agents are called radioreceptor assays, while a variation of the RIA, where the antibody is labelled instead of the antigen, is termed immunoradiometric assay.

The radioligand assays are all highly sensitive, but their specificity varies with the type of binding protein and the technique of sample extraction and purification employed. RIA has been the most widely used, owing to its versatility and practicability, and assays have now been developed for the measurement of a variety of hormones including proteo- and peptide-hormones, endogenous steroids, phyto-hormones and synthetic anabolic steroids (Karg *et al.*, 1976).

Figure 2 *The basic principle of radioimmunoassay. The radioactivity in* (Ab — H*) *is proportional to* 1/H.



RADIOIMMUNOASSAY. This technique requires specific antibodies that will bind with the substance to be measured (Figure 2). In the case of protein hormones with high molecular weights (MW) there is no specific limitation to the production of antibodies in experimental animals, as the hormones are immunogenic *per se*. However, in the case of steroid hormones (MW 300 to 400) that are not immunogenic, they must first be coupled on to a carrier substance such as bovine serum albumin. The steroids then act as haptens and can be used for producing antibodies in species such as sheep, rabbits and guinea-pigs. The antisera are harvested at appropriate stages and examined for characteristics such as titre, affinity and specificity. The ideal antiserum should have a high specificity for the hormone to be measured (i.e., little or no cross-reactivity with related hormones) as well as a high affinity. Radiolabelled hormones (tracers) can be either obtained commercially or prepared in the laboratory. For most steroid hormones the isotope

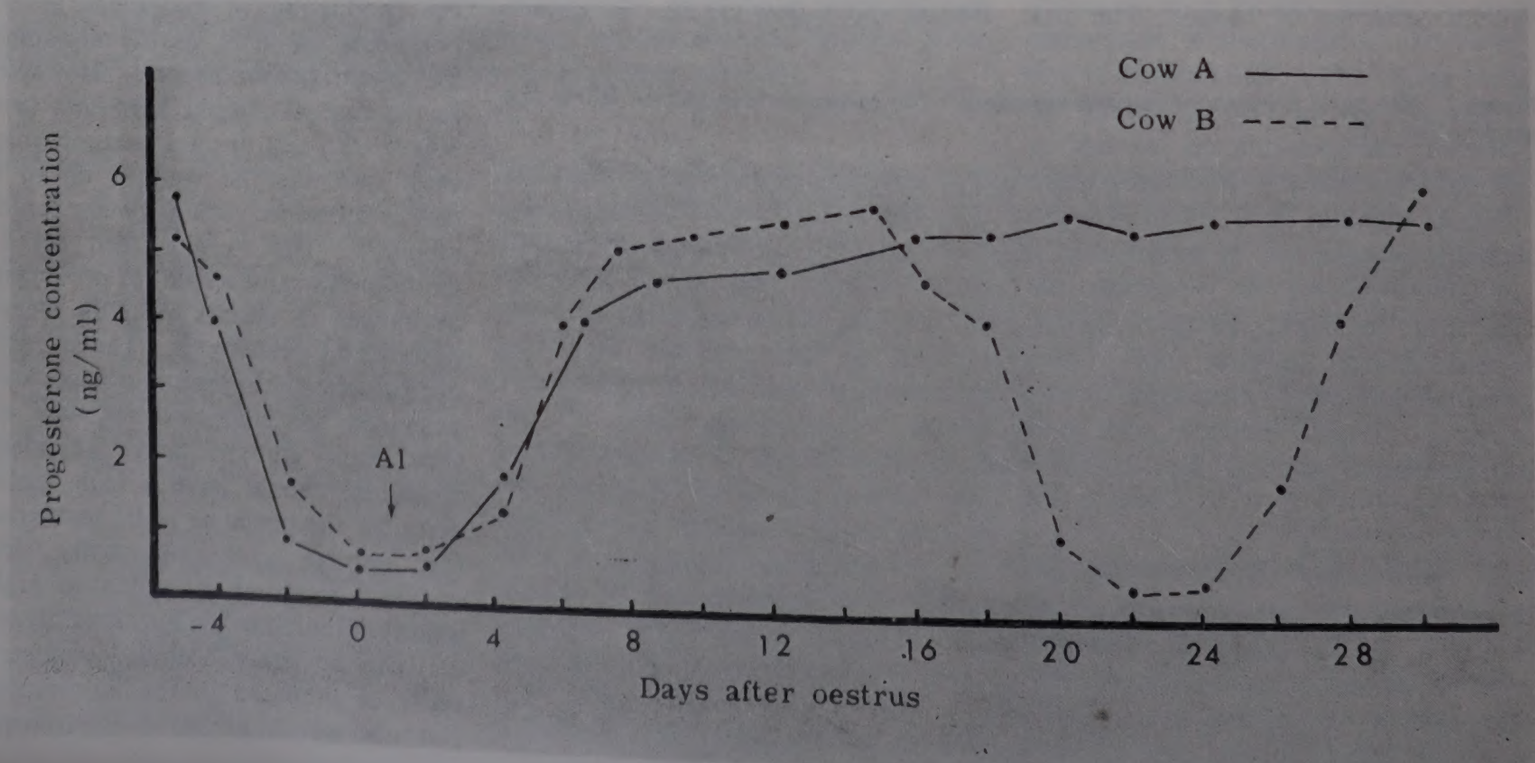
used is tritium (^3H), which is a beta (β)-emitter with a half-life of 12.3 years. Most proteo- and peptide-hormones, however, require labelling with radioactive iodine (^{125}I), which is a gamma (γ)-emitter with a short half-life of 60 days. The major requirement in terms of equipment is a facility for radioactivity measurement. If the isotope to be measured is ^3H a liquid scintillation counter is required, while for iodinated hormones a gamma counter (usually of the well-type with sodium iodide crystal) is needed.

The procedure for RIA, in a simplified form, is as follows. The hormone to be measured is extracted from a sample of plasma or serum (0.1 to 1.0 ml for most assays) using a suitable solvent. The extract is dried, suspended in a buffer solution and mixed with a known amount of radioactive hormone. The mixture is incubated with the antiserum in a suitable dilution for periods ranging from 2 to 24 hours. The hormone present in the unknown sample (unlabelled antigen) competes against the radioactive hormone (labelled antigen or tracer) for binding to a limited amount of antibody. The larger the amount of hormone in the unknown sample, the smaller is the amount of tracer hormone bound to the antibody, leaving a greater proportion of the added tracer unbound or "free". The distribution of tracer between the free and bound moieties is estimated by measuring the radioactivity in either of the two fractions, or in both.

A series of tubes containing known standard solutions of the hormone is included with each assay, and is used for constructing the dose-response curve. The unknown samples are quantified by comparing the response elicited by each against the standard curve. When an RIA for any particular hormone is newly established in a laboratory the assay needs to be validated by examining its specificity, accuracy, precision and sensitivity (Abraham *et al.*, 1971). Routine quality control procedures are also essential in order to monitor the reliability of the assay over periods of time.

Practical applications. Although assays for most types of reproductive hormones find ready applications in research, those which have been of greatest practical importance for improving reproductive performance are the progesterone assay in the female and the testosterone assay in the male. In non-pregnant female farm animals the concentration of progesterone in peripheral blood is an accurate index of the presence or absence of a functional CL. Thus progesterone level is low during the follicular phase of the oestrous cycle, and rises during the luteal phase (Figure 3). If the animal has not conceived during the previous oestrus the progesterone level will decline about 3 to 5 days before the next oestrus is due, whereas if conception had occurred the level will remain elevated until the approach of parturition. Any pathological condition that causes a persistence of the CL also results in a prolonged period of high progesterone concentration in blood. In cattle, the finding that progesterone concentration in milk is parallel to and higher than that in blood (Heap *et al.*, 1973) has extended the possible practical applications of measuring this hormone. This is chiefly due to the ease with which milk samples can be collected and dispatched to a laboratory for hormone assay, making it unnecessary for a skilled person to be available (as would be required for the collection of blood samples). It should be stressed, however, that care and uniformity are needed in collecting milk samples and in removing aliquots for assay, since progesterone concentration is influenced by the fat content of the

Figure 3 *Progesterone concentration in peripheral blood plasma of two cows after artificial insemination. Cow A has conceived while cow B has not.*



A proportion of animals presented for insemination may not be in a stage of the oestrous cycle compatible with conception.

sample (Pope *et al.*, 1976).

In males of most farm animal species the concentraton of testosterone in blood shows marked fluctuations during a 24-hour period, with no definite circadian or diurnal pattern. This is termed an "episodic" pattern or profile, and, in order to obtain information regarding the androgenic status of males, it is necessary to measure testosterone in successive samples of blood, collected at 30- to 60-minute intervals over a period of 10 to 24 hours (Perera and Munro, 1976). It is, therefore, meaningless to attempt an interpretation of hormonal status on the basis of a single daily blood sample. One way of overcoming this limitation is to stimulate testosterone secretion by administering gonadotrophins (Lincoln, 1976). The resultant elevation in blood testosterone levels can then be detected by collecting two or three samples 60 to 120 minutes after treatment, and provides an indication of the secretory capacity of the testicular Leydig cells.

Some of the ways in which measurement of progesterone and testosterone can be utilized for improving reproductive performance are described below.

OESTRUS CONFIRMATION. One of the major limitations to increasing reproductive efficiency is the difficulty in detecting animals in oestrus. In dairy cattle, it is generally accepted that an experienced stockman, under the most favourable circumstances, can detect no more than 80 percent of animals coming into oestrus. In addition, up to 20 percent of animals so identified as being in oestrus may not actually be at this stage of the cycle. In the case of buffaloes, the degree of misclassification is usually much higher, due to the weak expression of oestrus signs in this species (Perera *et al.*, 1977). A method for the accurate detection of oestrus would, therefore, be extremely valuable in increasing reproductive efficiency.

Unfortunately, hormone assays are at present unable to provide a direct practical solution to this problem, owing to the frequent sampling necessary to detect the pre-ovulatory peaks of oestrogen and LH in blood, and the fact that results of such assays would be available too late for breeding to be done at the appropriate time. However, determination of progesterone concentration in blood or milk at the time of breeding can reveal whether the animal had been incorrectly identified as being in oestrus. A high concentration at this time indicates that the animal was not in oestrus and rules out the possibility of it becoming pregnant. In an artificial insemination (AI) service such cases could be regarded as "lost inseminations", and it has been estimated that 15 to 26 percent of animals presented for AI are not at a stage of the oestrous cycle compatible with conception (Karg *et al.*, 1976). The detection of such cases, although admittedly of a retrospective nature, is useful in that greater attention can be paid to animals that are likely to return to oestrus.

PREGNANCY DIAGNOSIS. The conventional method of pregnancy diagnosis in cattle and buffaloes is by palpation of the uterus *via* the rectum. Although this is undoubtedly the most practical and, in skilled hands, accurate technique available at present, its main disadvantage is that it can be reliably performed by most only after the sixth week or so of pregnancy. However, progesterone concentration in blood or milk at 19 to 24 days after service can give an indication of whether the animal is likely to be pregnant or not (Heap *et al.*, 1973; Pope *et al.*, 1976). This relies on the fact that animals that do not conceive will have low progesterone in their blood and milk during this period, which is the time they would be ex-

Milk samples are easier to collect than blood samples, and extend the possible field applications of progesterone measurement.

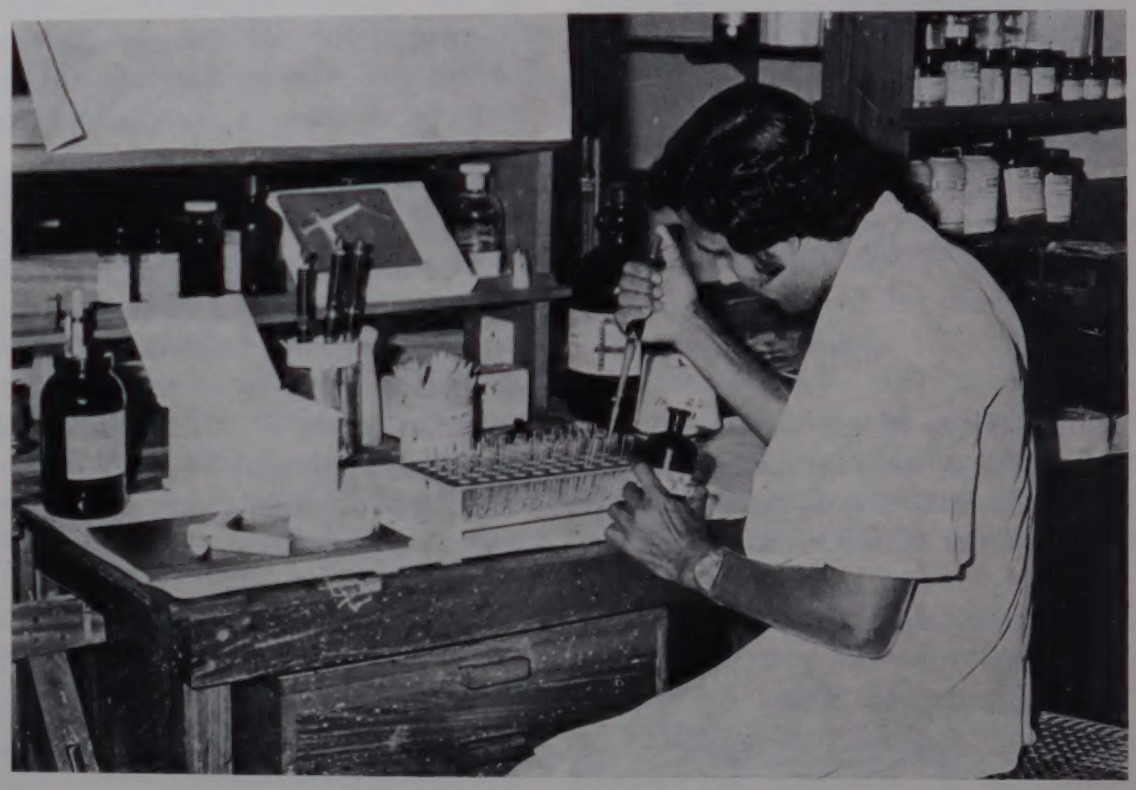
pected to return to oestrus, while those conceiving will have high concentrations persisting at the luteal phase levels (Figure 3). In cattle, the test is highly accurate for diagnosing non-pregnancy and 95 to 100 percent of animals with low progesterone concentrations are usually found subsequently to be empty. However, of the animals diagnosed as being pregnant on the basis of high progesterone levels, about 20 to 30 percent will be found to be non-pregnant when examined rectally at 45 to 60 days after service (Pope *et al.*, 1976). This is due mainly to embryonic death occurring during the period between the two pregnancy tests. Other causes for this overestimation of the pregnancy rate are irregularities of the oestrous cycle and persistence of the CL due to uterine pathology. This does not, however, detract from the value of the technique, since accurate identification of a high proportion of the non-pregnant animals allows appropriate action to be taken. The test can, therefore, be utilized as a tool for reducing the intercalving period.

This is at present one of the most useful practical applications of hormone assay in cattle and has been successfully introduced as a service to farmers in many developed countries. In England, for example, the Milk Marketing Board analyses around 8 000 samples of milk every month for early pregnancy diagnosis. The samples of milk are collected by the farmers themselves and posted to the laboratory, the results of the analyses being returned to the farmer within a week. This scheme could be suitably modified for introduction in developing countries, possibly in association with AI services and extension programmes, as an alternative to conventional pregnancy diagnosis services in regions where the major constraints are difficulties in transport between scattered smallholder farms and shortages of trained veterinarians.

This technique has also been shown to be applicable in buffaloes (Pandey, 1978; Perera, 1978), ewes (Shemesh, Ayalon and Lindner, 1973) and sows (Ellendorff, Meyer and Elsaesser, 1976). In buffaloes, where the detection of returns to heat after AI is more difficult than in cattle, the identification of non-pregnant animals by this method is particularly useful. In sheep it is also possible to predict lamb crop based on plasma progesterone concentration 80 to 100 days after mating (Van de Wiel, Visscher and Dekker, 1976). This enables the allocation of ewes bearing single and multiple foetuses to different feeding levels, thereby avoiding wastage of feed in the former group and preventing pregnancy toxaemia in the latter.

POST-PARTUM OVARIAN ACTIVITY. In order to achieve an optimum calving interval it is necessary that a resumption of cyclic ovarian activity after calving be detected as early as possible. Under normal circumstances, the first indication that an animal has started cycling is the occurrence of oestrus. It should be remembered, however, that onset of ovarian activity precedes this event by at least one cycle length, and is usually associated with an ovulation unaccompanied by oestrus. Furthermore, in the case of buffaloes, the poor expression of oestrus signs may result in failure to detect heat until a considerable period has elapsed after calving. This leads to delayed service and uneconomically lengthy calving intervals.

The onset of ovarian activity can be detected by measuring progesterone concentration in samples of blood or milk collected two to three times per week during the post-partum period. This enables the prediction of the first oestrus 6 to 11 days before it occurs (Rosenberg *et al.*, 1977). The ideal situation in dairy cattle is where progesterone secretion commences at 20 to 25 days after calving, with the first observable oestrus occurring at about 40 days. The monitoring of post-partum progesterone profiles is becoming increasingly important in modern systems of dairy husbandry and they are often included in herd fertility programmes. This facilitates the diagnosis of subfertility resulting from prolonged anoestrus (Lamming and Bulman, 1976) and is useful for the detection of conditions such as silent ovulation (ovulation without oestrus), false heat (oestrus without ovulation) and prolonged luteal phase, which are common causes of reduced reproductive efficiency during the post-partum period.



The cost involved in setting up a radioimmunoassay laboratory is usually more than justified by the returns in terms of improved reproductive efficiency.

REPRODUCTIVE DISEASE. An important clinical use of progesterone measurement is in the differential diagnosis of cystic ovarian degeneration in cattle (Dobson, Rankin and Ward, 1977).

It is often difficult, by rectal examination alone, to differentiate between follicular and luteal cysts. Recent findings indicate that these two types of cysts respond best to different treatment regimes. Progesterone levels in blood are, therefore, useful for confirming the nature of ovarian cysts. The response to the chosen line of treatment can also be monitored by measurement of progesterone in samples collected after treatment.

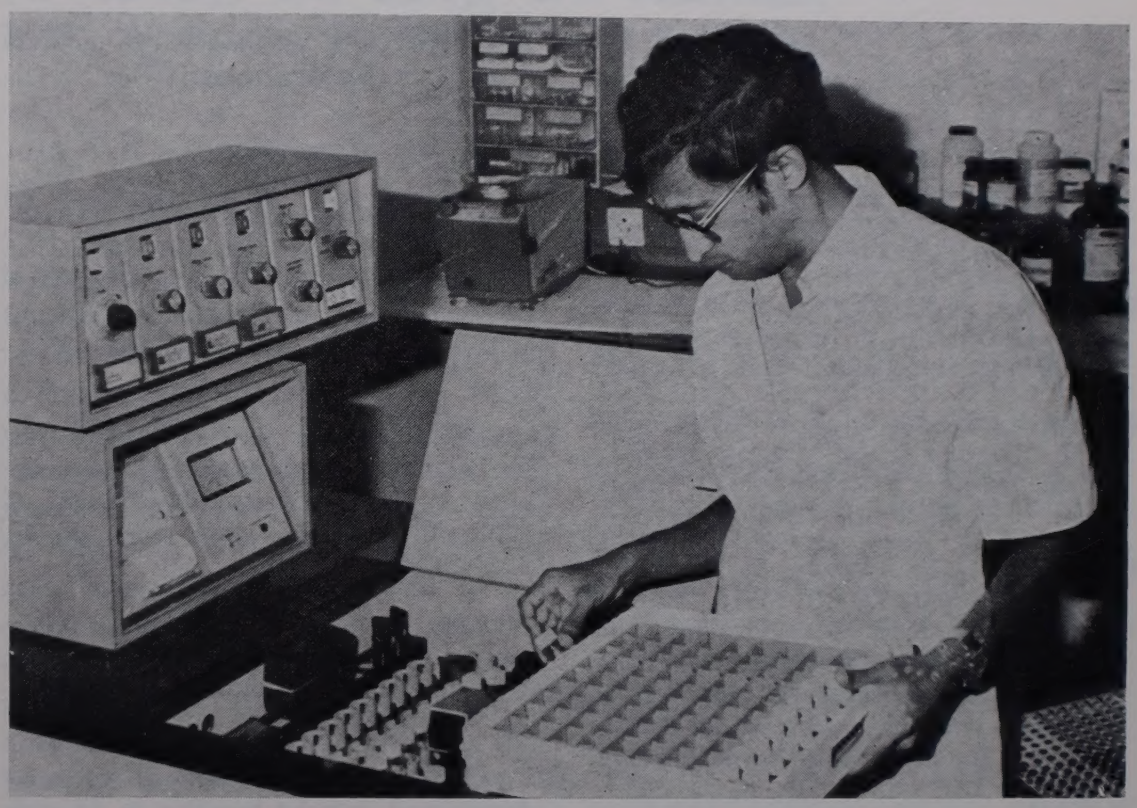
MALE REPRODUCTION. As mentioned earlier, male reproductive functions are androgen dependent. It should be emphasized, however, that in most species there is no clear linear relationship between androgen levels and characteristics such as libido or fertility. Although much controversy exists at present regarding the usefulness of androgen profiles for detecting disorders of male reproduction, recent work in bulls has shown that poor conception rates might be associated with low mean testosterone levels and lesser number of peaks of this hormone over a 24-hour period (Post and Christensen, 1976). If either the natural testosterone profile or the degree of elevation of testosterone after stimulation tests using gonadotrophins (Lincoln, 1976) is found to be of value in detecting differences in fertility or libido between individuals, it would be a convenient criterion for use in selection programmes. Further studies are, therefore, necessary to examine the applicability of these techniques for improving male reproductive efficiency.

calving intervals through oestrus confirmation, early diagnosis of non-pregnancy and monitoring of post-partum ovarian activity. Early pregnancy diagnosis based on milk progesterone assay has been launched as a commercial service for farmers in some countries, and has found an increasing demand. Similar applications are probably feasible in other species, but require further research and development.

These practical applications are also being attemped in some of the developing countries, but their use has not been sufficiently widespread to permit evaluation in terms of practicability, effectiveness and economic feasibility.

programmes for improving buffalo reproduction are presently receiving greater emphasis in the Asian region, and the basic studies necessary for elucidating the hormonal pattern of this species are under way in Thailand (Kamonpatana *et al.*, 1976), India (Pandey, 1978) and Sri Lanka (Perera *et al.*, 1978). These studies have demonstrated many dissimilarities between the reproductive patterns of cattle and buffaloes. It has also become evident, however, that the technologies being applied for improving reproduction in cattle can be adapted for use in buffaloes.

This illustrates the importance of basic research before practical applica-



A liquid scintillation counter for measuring radioactivity.

Conclusions. Methods of hormone assay have undergone a remarkable degree of development over the past decade. The major advances have been in their sensitivity, precision and convenience in practice. Meanwhile, these techniques have proved to be of considerable value in attempts to increase reproductive efficiency in farm animals. The variety of practical applications for which they are being currently employed in the developed countries reflects their importance in modern systems of animal production. In cattle they have made significant contributions toward achieving shorter

The costs involved in undertaking hormone assays might at first appear to preclude their use in developing countries. It should be remembered, however, that the gains to be expected from applying these techniques for the rapid multiplication of genetically superior stock in elite herds would be substantial and economically worthwhile in the long term. A further advantage would be the generation of data on reproductive problems under local conditions, which is an essential basis for developing appropriate technologies aimed at improving reproductive performance. For example,

tions can be evolved. Of particular importance in this regard, especially in developing countries, is the use of RIA to study endocrinological aspects of interactions between genotype and tropical environments. It has been shown that seasonal factors and heat stress can alter progesterone patterns in cattle (Rosenberg *et al.*, 1977). Studies in this direction should prove useful in examining the causes of impaired fertility in temperate breeds kept under tropical conditions and in identifying genotypes more tolerant to such environments. In buffaloes too, the seasonal pattern of fertility and the

causes for delay in return to post-partum cyclicity merit further investigation. It should be stressed, however, that hormone estimations should not be undertaken in isolation of other studies on physiological and clinical aspects of reproduction. To be meaningful, such studies should run parallel and should be interpreted in the light of hormonal, clinical and environmental, including nutritional, factors. In the male farm animals the use of testosterone assay is at present restricted mainly to research. There are indications, however, that useful practical applications might be developed in the near future, particularly for the selection of animals for better fertility or libido.

With regard to assay methodology, a desirable development would be a milk progesterone assay with greater accuracy and precision, while retaining the simplicity and speed of the current non-extraction procedure for whole milk (Pope *et al.*, 1976). This assay, although useful for practical purposes to detect CL activity, is not of sufficient accuracy at present for research purposes. A further problem in the case of buffaloes is the high fat content in milk, and the attendant difficulties in sampling and assay. These aspects should be studied in greater detail since the use of milk samples is mandatory for large-scale application of hormone assay techniques. A further development that appears to hold promise is the use of non-isotopic methods such as enzyme immunoassay. These techniques do not require expensive instrumentation, and could prove more acceptable than RIA in certain situations.

In conclusion it can be said that the field of reproduction has been particularly fruitful for the useful application of hormone assay techniques. The diversity of purposes for which the measurement of a single hormone such as progesterone can be utilized is truly remarkable. Further developments would no doubt point the way to other avenues of improving reproductive hormones in different physiological and pathological conditions. ■

References

ABRAHAM, G.E., SWERDLOFF, R., TULCHINSKY, D. & ODELL, W.D. 1971. Radioimmunoassay of plasma progesterone. *J. clin. Endocr.*, 32: 619-624.

BERSON, S.A. & YALOW, R.S. 1959. Assay of plasma insulin in human subjects by immunological methods. *Nature*, 184:1648.

DOBSON, H., RANKIN, J.E.F. & WARD, W.R. 1977. Bovine cystic ovarian disease: plasma hormone concentrations and treatment. *Vet. Rec.*, 101: 459-461.

EDQVIST, L.E., HAGGSTROM, A., KINDAHL, H. & STABENFELDT, G.H. 1976. Radioisotopic techniques for the study of reproductive physiology in domestic animals: 1. Assay procedures. In *Nuclear techniques in animal production and health*. Vienna, International Atomic Energy Agency. IAEA-SM-205/3, p. 513-523.

ELLENDORFF, F., MEYER, J.N. & ELSAESSER, F. 1976. Prospects and problems of pregnancy and fertility diagnosis in the pig by aid of progesterone determination. *Br. vet. J.*, 132: 543-550.

HEAP, R.B., GWYN, M., LAING, J.A. & WALTERS, D.E. 1973. Pregnancy diagnosis in cows: changes in milk progesterone concentration during the oestrous cycle and pregnancy measured by a rapid radioimmunoassay. *J. agric. Sci.*, 81: 151-157.

KAMONPATANA, M., LUVIRA, Y., BODHIPAKSHA, P. & KUNAWONGKRIT, A. 1976. Serum progesterone, 17-hydroxyprogesterone and 17-oestradiol during the oestrous cycle in the swamp buffalo in Thailand. In *Nuclear techniques in animal production and health*. Vienna, International Atomic Energy Agency. IAEA-SM-205/7, p. 569-577.

KARO, H., CLAUS, R., HOFFMANN, B., SCHALLENBERGER, E. & SCHAMS, D. 1976. Present status and future possibilities of radioimmunoassay in animal production. In *Nuclear techniques in animal production and health*. Vienna, International Atomic Energy Agency. IAEA-SM-205/109, p. 487-510.

LAMMING, G.E. & BULMAN, D.C. 1976. The use of milk progesterone radioimmunoassay in the diagnosis and treatment of subfertility in dairy cows. *Br. vet. J.*, 132: 507-517.

LINCOLN, G.A. 1976. Seasonal variation in the episodic secretion of luteinizing hormone and testosterone in the ram. *J. Endocr.*, 69: 213-226.

PANDEY, R.S. 1978. Hormonal status of female and induced breeding in Murrah buffaloes. *Proceedings of an FAO/SIDA Seminar on reproduction and artificial insemination of buffaloes*. Karnal, India, National Dairy Research Institute. (In press)

PERERA, B.M.A.O. 1978. Synchronization of oestrus and fertility in buffaloes of Sri Lanka. *Proceedings of an FAO/SIDA Seminar on reproduction and artificial insemination of buffaloes*. Karnal, India, National Dairy Research Institute. (In press)

PERERA, B.M.A.O. & MUNRO, C.D. 1976. Androgen levels in intact and vasectomized rams during the breeding and non-breeding seasons. *Fert. Steril.*, 27: 1446-1451.

PERERA, B.M.A.O., PATHIRAJA, N., KUMARATILAKE, W.L.J.S., ABEYRATNE, A.S. & BUVANENDRAN, V. 1977. Synchronization of oestrus and fertility in buffaloes using a prostaglandin analogue. *Vet. Rec.*, 101: 520-521.

PERERA, B.M.A.O., PATHIRAJA, N., BUVANENDRAN, V., ABEYWARDENA, S.A. & PIYASENA, R.D. 1978. Plasma progesterone levels during natural and prostaglandin-synchronized oestrous cycles in buffaloes. *Ceylon vet. J.*, 26. (In press)

POPE, G.S., MAJZLIK, I., BALL, P.J.H. & LEAVER, J.D. 1976. Use of progesterone concentrations in plasma and milk in the diagnosis of pregnancy in domestic cattle. *Br. vet. J.*, 132: 497-506.

POST, T.B. & CHRISTENSEN, H.R. 1976. Testosterone variability and fertility in bulls. *Eighth Annual Conference of the Australian Society for Reproductive Biology. Animal Breeding Abstracts 1977*, 45: 333.

ROSENBERG, M., HERZ, Z., DAVIDSON, M. & FOLMAN, Y. 1977. Seasonal variations in post-partum plasma progesterone levels and conception in primiparous and multiparous dairy cows. *J. Reprod. Fert.*, 51: 363-367.

SHEMESH, M., AYALON, N. & LINDNER, H.R. 1973. Early pregnancy diagnosis based upon plasma progesterone levels in the cow and ewe. *J. Anim. Sci.*, 36: 726-729.

VAN DE WIEL, D.F.M., VISSCHER, A.H. & DEKKER, T.P. 1976. Use of a radioimmunoassay of plasma progesterone for predicting litter size and subsequent adaptation of feeding level in sheep. In *Nuclear techniques in animal production and health*. Vienna, International Atomic Energy Agency. IAEA-SM-205/1, p. 547-553.

This review of the prospects for developing an immunization procedure against trypanosomiasis explores a number of promising avenues of research. Part I covers variable antigen types (VATs); metacyclic antigens; *in vivo* and *in vitro* attenuation; and molecular and genetic engineering. Part II, to be included in the next issue of this journal, will cover immunogenicity of subcellular fractions; immunological intervention against the tsetse fly; induction of increased resistance by immunostimulants; trypanotolerance; and infection and treatment. This will be followed by a brief statement of the conclusions reached.

A review of the prospects for vaccination in African trypanosomiasis

Part I

M. Murray, J.D. Barry, W.I. Morrison, R.O. Williams, H. Hirumi and L. Rovis

The present methods available for the control of African trypanosomiasis, namely, systematic case detection and treatment, and tsetse control, do no more than limit the disease although both these approaches have been shown to be effective where they have been vigorously applied. The disadvantages attending the use of trypanocidal drugs include lack of availability of effective drugs, drug resistance and, in heavy tsetse fly challenge areas, the frequency with which treatment has to be applied, often to economically unacceptable levels. In the same way, while tsetse flies may be completely eradicated in certain areas by insecticide control, few regions of tsetse infestation have circumscribed boundaries and, unless cleared areas are defended (a costly exercise), reinvasion by the tsetse fly inevitably occurs. Thus there is little doubt that the introduction of an effective vaccine, if used strategically along with established control methods, would make an enormous contribution to the control of African trypanosomiasis, not only by increasing productivity in endemic trypanosome areas but also by opening up for exploitation the vast areas of the African continent largely devoid of livestock because of trypanosomiasis.

The major constraint to developing a trypanosome vaccine is the ability of the parasite to undergo antigenic variation. Murray and Urquhart (1977) reviewed the various attempts made to vaccinate both domestic livestock and laboratory animals and it was obvious from the reported studies that complete protection was readily achieved only if the same variable antigen type (VAT) was used for immunization and challenge. When a distinct VAT was used for challenge no protection occurred. Therefore, it would appear that an effective vaccine would have to contain all VATs, possibly an insurmountable task as the number of VATs, although as yet undetermined, is likely to be large. The result is that many workers in trypanosomiasis research consider the possibility of vaccination to be remote. It should be borne in mind, however, that many of these conclusions have been drawn from work on laboratory animals, which invariably succumb to massive parasitaemia. There is evidence to show that under certain circumstances cattle can control parasitaemia and then clinically recover. While this is particularly true for trypanotolerant breeds such as the N'Dama, it can also occur in the more susceptible zebu (Stewart, 1951; Chandler, 1958; Desowitz, 1959; Wilson, 1971; Wilson and Cunningham, 1971 and 1972; Murray *et al.*, 1979). The greater capability of the bovine to control parasitaemia creates a new perspective on the question of vaccination. Furthermore, advances in scientific knowledge and technology have opened up several different avenues of research and the present article attempts to explore these.

Variable antigen types (VATs). Antigenic variation, the major obstacle to developing a trypanosome vaccine, is the process whereby trypanosomes sequentially express a series of surface antigens; it is these antigens that are capable of inducing protective immunity. The immune response against each variant, although rapid and highly effective in destroying any trypanosomes that possess that particular antigen, is invariably too late to affect that proportion of the population that has altered its antigenic identity. Thus, parasitaemia rises and falls in waves with each parasite population carrying different surface antigens (reviewed by Cross, 1978; Vickerman, 1978). This picture of successive

The authors are with the International Laboratory for Research on Animal Diseases (ILRAD), PO Box 30709, Nairobi, Kenya.

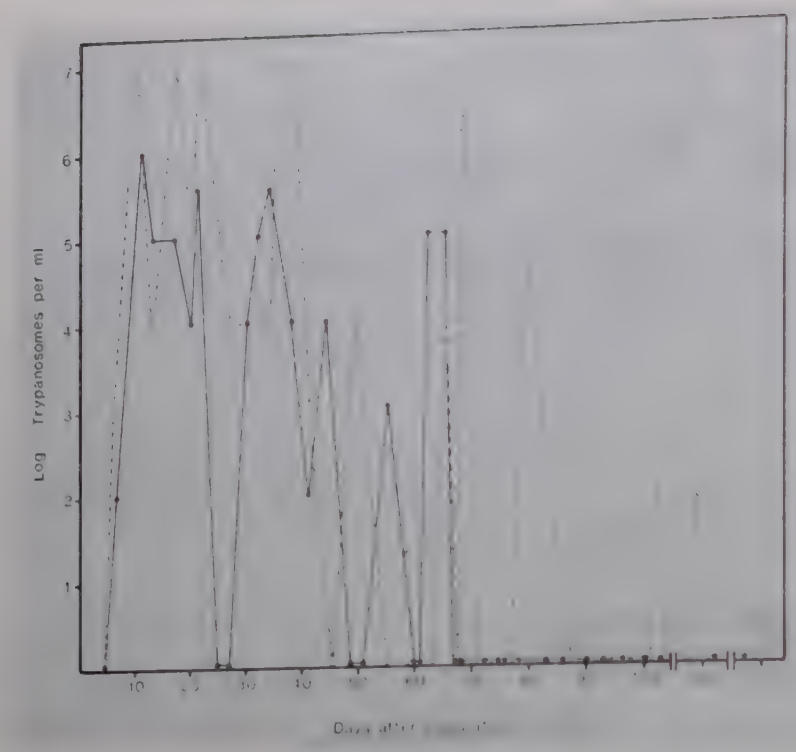


Figure 1 *Parasitaemia profile in an individual four-year-old N'Dama* (•) *and a four-year-old zebu* (o) *inoculated with* Trypanosoma congolense. *Note that the level of parasitaemia is lower in the N'Dama as is the duration of parasitaemia. Both animals were negative for detectable parasites for several months prior to the termination of the experiment and both made a clinical recovery.*

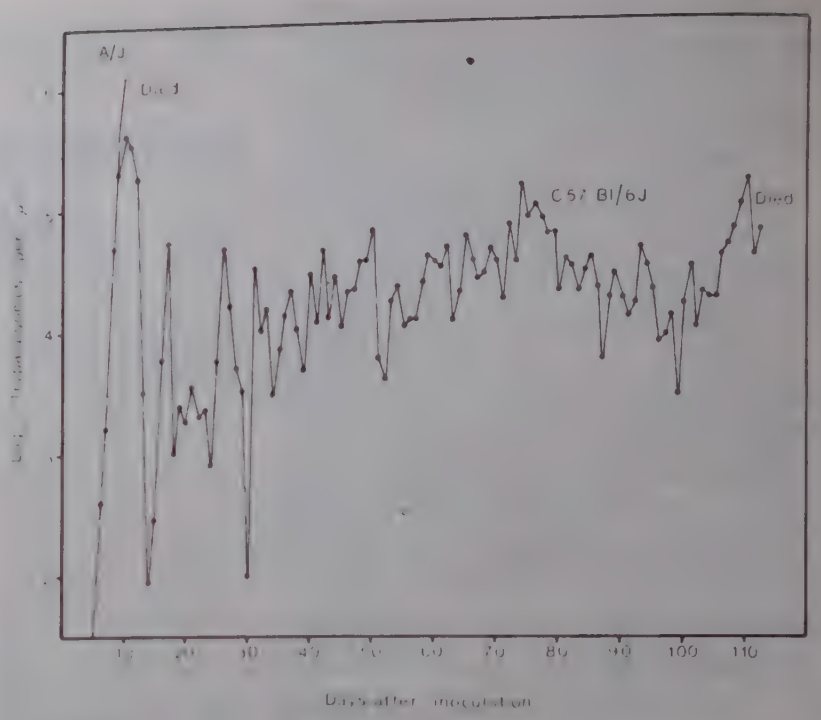


Figure 2 *Parasitaemia profile in an individual C57Bl/6J mouse* (•) *and A/J mouse* (o) *inoculated with* Trypanosoma congolense. *The C57Bl/6J was able to control and reduce parasitaemia levels to a significantly greater extent than the A/J and as a result was able to survive for over 100 days. Irrespective of breed or strain, cattle were able to control and reduce parasitaemia to a much greater extent than mice. Following infection in mice, death was inevitable, whereas in cattle recovery may occur, particularly in N'Dama animals.*

waves of a specific antibody chasing variant trypanosomes has been likened by Goodwin (1970) to a "Tom and Jerry cartoon with a monstrously inept cat pulling the place down in its efforts to pulverize a diminutive and highly resourceful mouse".

What would appear to be required is as complete as possible an understanding of antigenic variation in order that, eventually, it might be possible to produce an effective vaccine by the strategic use of certain trypanosomes or their components. At the population level, the authors' knowledge has been increasing over the past few years, thanks mainly to the concept of multiple cloning in which bloodstream populations are divided into their component parts, namely single trypanosomes, each of which gives rise, in a fresh host, to a defined population that can be frozen as reference material. It is essential that as large a number of clones as possible be isolated, since only then will it be possible to detect some of the subtle immunological and biological differences within and between populations.

This approach has begun to reveal what occurs within a parasitaemic peak, to the level of the individual parasite. It appears that a peak is usually a mixture of VATs (Van Meirvenne, Janssens and Magnus, 1975a) with the switch to expression of another type, probably occurring before the appearance of antibody, which is thought to act merely as a selective agent (Van Meirvenne, Janssens and Magnus, 1975a; Le Ray *et al.*, 1977). Examination of sequence of appearance of VATs arising within cloned infections has confirmed and extended the observation of Gray, 1965) that there is a tendency for certain types to occur preferentially in the early parasitaemic peaks. Thus, it would appear that VATs can be divided into these early "predominant" types and other groups of VATs that occur later (Van Meirvenne, Janssens and Magnus, 1975a; Capbern *et al.*, 1977).

The total number of VATs that a trypanosome can express is known as its "VAT repertoire," the full extent of which is as yet unknown although Capbern *et al.* (1977) have been able to isolate 101 VATs from one clone of *Trypanosoma equiperdum*. Comparison of VAT repertoires from different clones has been initiated (Van Meirvenne *et al.*, 1975b; Van Meirvenne, Magnus and Vervoort, 1977) and has revealed a surprisingly high degree of similarity; in fact, some VATs have been found in every repertoire examined. In addition, there is now indirect evidence from serological studies that during an infection certain VATs may recur, in some cases within a few weeks of one another. This has been described in cattle infected with *Trypanosoma congolense* (Wilson and Cunningham, 1971) and with *T. brucei* (Nantulya, Musoke, Barbet and Roelants — unpublished results).

As regards vaccination, a rational approach may be successful. Immunization against individual VATs is highly effective using such regimes as infection and treatment; irradiated organisms; killed organisms; crude emulsions containing released soluble antigens; formalized whole infected blood or plasma and purified variable antigen glycoprotein (reviewed by

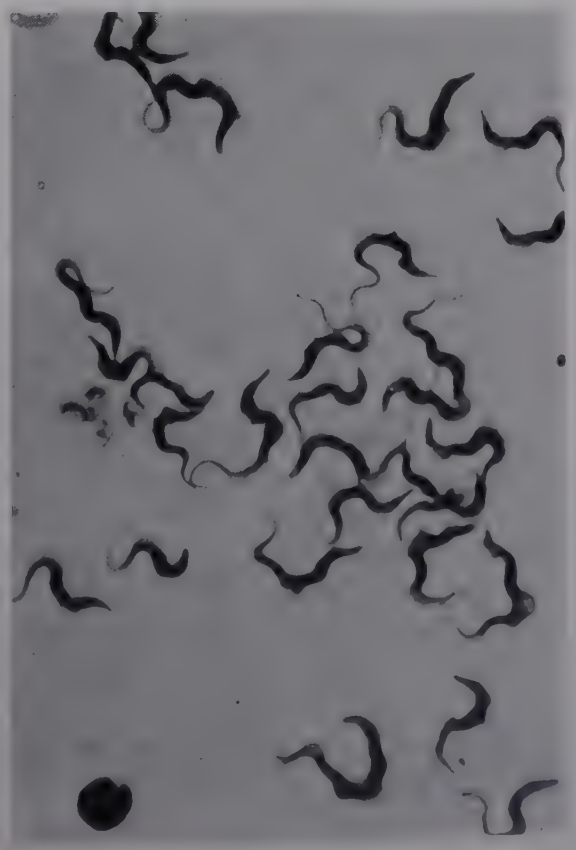
Murray and Urquhart, 1977). As little as 3 μg of variable antigen can give protection in mice (Baltz *et al.*, 1977). A cocktail vaccine based on predominant VATs is likely to be effective against trypanosomes with that repertoire. Investigation of the feasibility of such an approach requires complete analyses of the number of VATs, both predominant and otherwise, within a repertoire, of the extent of cross-reaction between repertoires and, eventually, of the number of VATs that exist within and without given geographical areas.

A word of warning regarding studies on antigenic variation: it is necessary to define not only the parasite but also the host. The parasitaemic patterns produced by a trypanosome will vary with species of host, breed or strain, age, sex, etc. (Figures 1 and 2). In this regard, there is little doubt that exploitation of the *in vitro* culture system, which supports the growth of animal-infective forms of trypanosomes (Hirumi, Doyle and Hirumi, 1977) by eliminating the variable effects of the host, must yield new information on the basis and mechanisms of antigenic variation. Since much of the above work has been carried out with *T. brucei* the authors believe that it is essential that similar efforts be made with *T. congolense* and *T. vivax*, which are regarded as the major pathogens of bovine African trypanosomiasis.

Metacyclic antigens. Following ingestion by the tsetse fly, *T. brucei* loses its surface coat, which contains the variable antigen. It eventually regains the coat in the fly's salivary gland in becoming the mammalian-infective metacyclic stage (Vickerman, 1969). It has been suggested that all trypanosomes of a particular clone revert to a common "basic" antigen type in the salivary gland (Jenni, 1977, for *T. brucei;* Nantulya, Doyle and Jenni, 1979, for *T. congolense*) akin to the "basic" type arising in the bloodstream after cyclical transmission (Gray, 1965). Vaccination against such types would obviously be of importance. However, there is now evidence to suggest that this is not the case and that *T. brucei* metacyclics

Figure 3 *Antigenic heterogeneity among mammalian-infective metacyclic forms in the saliva of a tsetse fly. The fly was allowed to salivate onto a heated glass slide, to which immunofluorescence was applied using specific antiserum against a characterized bloodstream form trypanosome* VAT. *Metacyclics with trypanosome* VAT *fluoresce strongly, while those of other* VAT *display the weak fluorescence of the counterstrain.*

Figure 4 *Bloodstream forms of* Trypanosoma brucei (*ILR-TbC-221*) *grown* in vitro *for over 31 months. Giemsa's stain.*



arising from the passage of a clone through the tsetse are antigenically heterogeneous (Figure 3) (Le Ray, Barry and Vickerman, 1978; Barry and Hajduk, 1979; Barry *et al.*, 1979b), although it is still the case that there may be only a limited number. A drawback to the potential use of metacyclic populations for vaccination is that they are antigenically unstable (Le Ray *et al.*, 1977; Le Ray, Barry and Vickerman, 1978), preventing mass production of antigen and mRNA (see later, molecular and genetic engineering) for potential vaccine preparation. However, these difficulties may be overcome by a recently devised protocol (Barry *et al.*, 1979b) whereby antigenically more stable mammalian bloodstream forms with the same VAT as metacyclics can be identified and cloned giving rise to populations suitable for bulk preparative procedures. This approach could be pursued to define the VAT complement of metacyclic populations with a view to vaccination against trypanosomes of that VAT repertoire. Furthermore, it is essential to determine the degree of cross-reaction between metacyclics of different repertoires.

The *in vitro* culture system would also appear to have potential in this area. It has now been shown that "bloodstream forms" of *T. brucei* in culture (Figure 4) can be induced to undergo morphological changes similar to those that occur in the fly, including the eventual production of metacyclic types, by appropriate manipulation of the culture conditions (Hirumi, Hirumi and Doyle, 1978a). As it has now become possible to clone parasites in culture (Hirumi, Hirumi and Doyle, 1978b) this approach might offer a source of metacyclic types of defined antigenic identity.

***In vivo* and *in vitro* attenuation.** Another facet of the problem is that, despite the authors' steadily increasing knowledge of antigenic variation, very little is known of how it is linked to the biology of the trypanosome and the host-parasite interaction, apart from the fact that it allows the trypanosome to evade the host's immune response and thus survive. For ex-

ample, an association between VAT and virulence has been proposed (McNeillage and Herbert, 1968; Van Meirvenne, Janssens and Magnus, 1975a) although it is essential that the precise circumstances of such a link are fully investigated (Barry, Le Ray and Herbert, 1979a). It is a common mistake to equate the VAT of a clone with all the characteristics displayed by that clone; the VAT is just one phenotypic marker. Confirmation of a link between VAT and virulence, and the observation that trypanosomes of different VAT may interfere with the expression of each other at the population level (Herbert, 1975) conceivably could be exploited to decrease the number of variable antigens required in a vaccine. At a later stage of infection, after expression of predominant VATS, it appears that trypanosomes are in some way biologically altered as evidenced by their decreased infectivity and virulence in fresh hosts. The basis of this and whether it is linked to VAT or some other characteristic of the parasite remains to be investigated.

Can these changes in behaviour be induced artificially and incorporated into a vaccination protocol? The possibility now exists of attenuating trypanosomes by continuous passage in culture. In preliminary studies, it has been found that mice infected with parasites maintained *in vitro* by serial subcultivation over 12 months have shown alteration in pathogenicity when compared with non-cultured organisms or organisms that have been maintained *in vitro* for less than three months (Hirumi, unpublished data). The potential protective effect of attenuated protozoa has already been demonstrated in the control of babesiosis in cattle in Australia (Callow, 1977).

Molecular and genetic engineering. There is little doubt that the basis of understanding antigenic variation will come from investigations of the molecular biology of the trypanosome. *In vitro* cultivation techniques and recently developed tools in biochemistry and genetic engineering have opened up new horizons. Thus studies of the type carried out by Williams *et al.* (1978) on trypanosomal RNA will provide much essential information on trypanosome biology. Reannealing studies on the nucleic acid coding for the VAT repertoire should give an insight into the size of the repertoire, the extent of similarity between different repertoires and the molecular nature of the genes involved. The genetic control of expression of antigenic variation should be studied; artificial restriction of a trypanosome population to expression of only a limited number of its VATS might allow effective vaccination.

In any discussion of vaccination, consideration must be given not only to the obvious application of these newly developed techniques to antigen production but also to novel approaches to vaccination. It is possible that in the near future many protein vaccines will be produced from large-scale bacterial cultures that contain the gene sequences coding for the appropriate proteins. Recombinant DNA technology has already been applied to the large-scale production of human somatomammotropin (growth hormone) (Shine *et al.*, 1977), a precious substance that has traditionally been isolated from human placenta.

A further example of the application of recombinant DNA technology to vaccine production is the development of a bacterial strain that is capable of producing the native chick-albumin protein at a level of 10 percent by weight of the bacterial cell (Mercereau-Puijalou *et al.*, 1978). Thus bacterial strains can be developed to produce proteins for vaccines that normally would be either too expensive to isolate or impossible to purify because of limited amounts of starting material.

In addition to vaccine production in bacteria recent reports describe new techniques that possibly could find application in vaccination procedures. The transfer of specific genes from one genome to another has now been achieved. An example of such a transfer was reported by Wigler *et al.* (1978) where a specific viral gene coding for the enzyme thymidine kinase was purified by electrophoresis and introduced into a thymidine-kinase-deficient tissue-culture cell line. Many of the tissue-culture cells were able not only to incorporate the DNA sequence into their genome but also were able to produce the enzyme at apparently normal levels. It may be possible, therefore, to modify certain tissues during a proliferative stage so as to yield a gene product to correct a genetic deficiency or possibly to produce a foreign protein for use in vaccination.

In other novel procedures recently reported by Dimitriadis (1978) and Ostro *et al.* (1978), differentiated tissue cultures were modified to produce a specific protein for a limited time. In each of these reports, a specific purified messenger RNA (rabbit globin) sequence was encapsulated in a lipid micelle called a liposome. The liposome was introduced to tissue-culture cells with the membrane of which the liposome presumably fused. The purified messenger RNA was thereby introduced into the cytoplasm of the cells where it was translated into rabbit globin protein. The messenger RNAS used in such a procedure are degraded at a normal rate and can be modified to delay the cell's normal messenger RNA degradation processes. The normal cell's genome is not permanently modified and would produce the desired protein only for a limited time. In this manner, one could presumably use specific messenger RNAS and specific target tissues to produce the protein required for immunization. The inherent appeal of such a system would be that target tissues could produce sufficient quantities of a specific protein for a limited amount of time, thus allowing immunization to occur. Although such applications of molecular biology to vaccination are presently a dream, there is little doubt of their being a reality in the future. ■

References

BALTZ, T., BALTZ, D., PAUTRIZEL, R., RICHET, C., LAMBLIN, G. & DEGAND, P. 1977. Chemical and immunological characterization of specific glycoproteins from *Trypanosoma equiperdum* variants. *FEBS Letters*, 82: 93-96.

BARRY, J.D. & HAJDUK, S.L. 1979. Antigenic heterogeneity of bloodstream and metacyclic forms of *Trypanosoma brucei*. In *Recent advances in the knowledge of*

pathogenicity of trypanosomes. Ottawa, Canada, IDRC. (In press)

Barry, J.D., Le Ray, D. & Herbert, W.J. 1979a. Infectivity and virulence of *Trypanosoma* (*Trypanozoon*) *brucei* for mice. IV. Dissociation of virulence and variable antigen type in relation to pleomorphism. *J. comp. Path.* (In press)

Barry, J.D., Hajduk, S.L., Vickerman, K. & Le Ray, D. 1979b. Detection of multiple variable antigen types in metacyclic populations of *Trypanosoma brucei*. *Transactions of the Royal Society of Tropical Medicine and Hygiene*. (In press)

Callow, L.L. 1977. Vaccination against bovine babesiosis. In *Immunity to blood parasites of animals and man*. Eds. L.H. Miller, J.A. Pino and J.J. McKelvey, Jr. New York and London, Plenum Press. Advances in Experimental Medicine and Biology. Vol. 93. p. 121-149.

Capbern, A., Giroud, C., Baltz, T. & Mattern, P. 1977. *Trypanosoma equiperdum:* étude des variations antigéniques au cours de la trypanosomose expérimentale du lapin. *Experimental Parasitology*, 42: 6-13.

Chandler, R.L. 1958. Studies on the tolerance of N'Dama cattle to trypanosomiasis. *J. comp. Path.*, 68: 253-260.

Cross, G.A.M. 1978. Antigenic variation in trypanosomes. *Proceedings of the Royal Society of London*, B 202: 55-72.

Desowitz, R.S. 1959. Studies on immunity and host-parasite relationship. I. The immunological response of resistant and susceptible breeds of cattle to trypanosomal challenge. *Annals of tropical Medicine and Parasitology*, 53: 293-313.

Dimitriadis, G.J. 1978. Translation of rabbit globin mRNA introduced by liposomes into mouse lymphocytes. *Nature*, 274: 923-924.

Goodwin, L.G. 1970. The pathology of African trypanosomiasis. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 64: 797-817.

Gray, A.R. 1965. Antigenic variation in a strain of *Trypanosoma brucei* transmitted by *Glossina morsitans* and *G. palpalis*. *Journal of general Microbiology*, 41: 195-214.

Herbert, W.J. 1975. Interference between two strains of *Trypanosoma brucei*. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 69: 272.

Hirumi, H., Doyle, J.J. & Hirumi, K. 1977. African trypanosomes: cultivation of animal-infective *Trypanosoma brucei in vitro*. *Science*, 196: 992-994.

Hirumi, H., Hirumi, K. & Doyle, J.J. 1978a. Cultivation, complete cyclic development and cloning of *Trypanosoma brucei in vitro*. *Fourth International Congress of Parasitology, 19-26 August 1978*, Warszawa, Poland. Section A: p. 54.

Hirumi, H., Hirumi, K. & Doyle, J.J. 1978b. Cloning of African trypanosomes in the presence of bovine fibroblast-like cells. *In vitro*, 14: 379.

Jenni, L. 1977. Comparisons of antigenic types of *Trypanosoma* (*T.*) *brucei* strains transmitted by *Glossina m. morsitans*. *Acta tropica*, 34: 35-41.

Le Ray, D., Barry, J.D., Easton, C. & Vickerman, K. 1977. First tsetse fly transmission of the "AnTat" serodeme of *Trypanosoma brucei*. *Annales de la Société belge de Médecine tropicale*, 57: 369-381.

Le Ray, D., Barry, J.D. & Vickerman, K. 1978. Antigenic heterogeneity of metacyclic forms of *Trypanosoma brucei*. *Nature*, 273: 300-302.

McNeillage, G.J.C. & Herbert, W.J. 1968. Infectivity and virulence of *Trypanosoma* (*Trypanozoon*) *brucei* for mice. II. Comparison of closely related trypanosome antigenic types. *J. comp. Path.*, 78: 345-349.

Mercereau-Puijalou, O., Royal, A., Cami, B., Garapin, A., Krust, A., Gannon, F. & Kourilsky, P. 1978. Synthesis of an ovalbumin-like protein by *Escherichia coli* K12 harbouring a recombinant plasmid. *Nature*, 275: 505-510.

Murray, M. & Urquhart, G.M. 1977. Immunoprophylaxis against African Trypanosomiasis. In *Immunity to blood parasites of animals and man*. Eds. L.H. Miller, J.A. Pino and J.J. McKelvey, Jr. New York and London, Plenum Press. Advances in Experimental Medicine and Biology. Vol. 93. p. 209-241.

Murray, M., Morrison, W.I., Murray, P.K., Clifford, J.D. & Trail, J.C.M. 1979. A review: trypanotolerance. *Wld Anim. Rev.*, 31. (In press)

Nantulya, V.N., Doyle, J.J. & Jenni, L. 1979. Studies on *Trypanosoma* (*Nannomonas*) *congolense*. III. Antigenic variation in cyclically transmitted strains. *Parasitology*. (In press)

Ostro, M.J., Giacomoni, D., Lavelle, D., Paxton, W. & Dray, S. 1978. Evidence for translation of rabbit globin mRNA after liposome-mediated insertion into a human cell line. *Nature*, 274: 921-923.

Shine, J., Seeburg, P.H., Martial, J.A., Baxter, J.D. & Goodman, H.M. 1977. Construction and analysis of recombinant DNA for human chrionic somatomammotropin. *Nature*, 270: 494-499

Stewart, J.L. 1951. The West African Shorthorn Cattle. Their value to Africa as trypanosomiasis-resistant animals. *Veterinary Record*, 63: 454-457.

Van Meirvenne, N., Janssens, P.G. & Magnus, E. 1975a. Antigenic variation in syringe passaged populations of *Trypanosoma* (*Trypanozoon*) *brucei*. I. Rationalization of the experimental approach. *Annales de la Société belge de Médecine tropicale*, 55: 1-23.

Van Meirvenne, N., Janssens, P.G., Magnus, E., Lumsden, W.H.R. & Herbert, W.J. 1975b. Antigenic variation in syringe passaged populations of *Trypanosoma* (*Trypanozoon*) *brucei*. II. Comparative studies on two antigenic-type collections. *Annales de la Société belge de Médecine tropicale*, 55: 25-30.

Van Meirvenne, N., Magnus, E. & Vervoort, T. 1977. Comparison of variable antigenic types produced by trypanosome strains of the subgenus *Trypanozoon*. *Annales de la Société belge de Médecine tropicale*, 57: 409-423.

Vickerman, K. 1969. On the surface coat and flagellar adhesion in trypanosomes. *J. Cell Sci.*, 5: 163-194.

Vickerman, K. 1978. Antigenic variation in trypanosomes. *Nature*, 273: 613-617.

Wigler, M., Pellicer, A., Silverstein, S. & Axel, R. 1978. Biochemical transfer of single-copy eucaryotic genes using total cellular DNA as donor. *Cell*, 14: 725-731.

Williams, R.O., Marcu, K.B., Young, J.R., Rovis, L. & Williams, S.C. 1978. A characterization of mRNA activities and their sequence complexities in *Trypanosoma*: *brucei* partial purification and properties of the VSSA mRNA. *Nucleic Acids Research*, 5: 3171-3182.

Wilson, A.J. 1971. Immunological aspects of bovine trypanosomiasis. III. Patterns in the development of immunity. *Tropical Animal Health and Production*, 3: 14-22.

Wilson, A.J. & Cunningham, M.P. 1971. Immunological aspects of bovine trypanosomiasis. IV. Patterns in the production of common antibodies. *Tropical Animal Health and Production*, 3: 133-139.

Wilson, A.J. & Cunningham, M.P. 1972. Immunological aspects of bovine trypanosomiasis. I. Immune response of cattle to infection with *Trypanosoma congolense* and the antigenic variation of the infecting organism. *Experimental Parasitology*, 32: 165-173.

Smallholder fattening of beef cattle in the Niger

C. Wardle

results from a pilot scheme

During the recent drought that struck the Sahel between 1968 and 1973 livestock were greatly affected. In the Niger alone the national cattle herd shrank from an estimated 4.2 million head to 2.2 million by 1974 (Ministère de l'économie rurale, 1974). Priority in this country has been given to rebuilding decimated herds. At the same time, steps are being taken to increase the productivity of existing herds (Ministère du plan, 1977).

The productivity of the livestock sector in the Niger is relatively low, at least when compared with European or North American standards. The offtake rate for the nation's cattle herd was estimated at 12.5 percent in 1971 with annual meat production per animal averaging 14 kg (Haladou, 1974). The reasons for the low productivity lie partly with the harsh environment of the Sahel, and partly with the attitude of the herders. These are largely nomadic or semi-nomadic people, whose approach differs from that of livestock farmers in Europe or North America. For them, cattle serve varied functions. Maximizing revenue from their herds is not necessarily their prime objective (Eddy, 1975).

Nevertheless, the herders do sell some of their cattle, every so often, in order to purchase millet, the staple grain in the Niger, as well as to buy other necessities and to pay their taxes. Unless these cattle are sold during or shortly after the rainy season, when forage is abundant, they are unlikely to be in prime condition. As the dry season advances, grazing dries up and may become scarce. Progressively, the cattle lose much of the weight gained during the short rainy season.

During the dry season, the herders cannot fatten their cattle very well before sale. Few grow crops and so do not possess by-products that could be used for supplementary feeding. Furthermore, the herders are often on the move in search of new grazing areas. An animal given any supplementary feeding is liable quickly to walk off any weight it may gain.

However, small farmers living in the southern part of the Niger, where rainfall is sufficient to permit the growing of certain crops, have the necessary by-products for fattening at their disposal. These by-products, such as millet and rice bran, are often underutilized. Unfortunately, many

MR WARDLE's present address is 1A Bewdley Street, London N1, United Kingdom. This article is based on work undertaken by him as manager of a smallholder cattle-fattening project financed by Euro Action Acord, The Netherlands.

of the small sedentary farmers have limited experience with cattle. In addition, few have the necessary capital to finance the purchase of cattle for fattening.

The project. The project at Libore (Ministère de l'économie rurale, 1974) had as its main objective to determine if small farmers could be encouraged to fatten cattle sold by the herders during the dry season. The project was also expected to quantify the returns to farmers from fattening as well as identify problems encountered when promoting this new activity. This and other information would prove useful to the Service de l'élevage when planning future projects. The project was funded by Euro Action Acord, a consortium of non-governmental agencies, and commenced operations early in 1976. Control of the project rested in the hands of the Ministère de l'économie rurale.

The project was limited to the canton of Libore situated south of Niamey, the capital of the Niger, on the banks of the Niger river. Population in the 14 villages was estimated at 8 275 in 1974.

The project obtained credit in the form of loans available to farmers to purchase cattle for fattening. Each farmer was responsible for the purchase of his own cattle, though all animals were checked after purchase to ascertain that they were healthy and of suitable size. The minimum length of the fattening period was fixed at three months and the maximum at six months, by which time the loans had to be repaid in full. A moderate rate of interest was charged, starting at 5.5 percent and eventually rising to 8.0 percent per annum. The increase was made in order to bring the interest rate in line with that charged by other agricultural and livestock credit programmes in the Niger. The cattle were kept in their owners' compound tied to a tree or stake. All forage, feed and water were brought to them.

Results obtained. The results obtained during the first two years indicate that small farmers are quite capable of fattening cattle; that if done reasonably well, the activity is profitable; that small farmers respond positively to the monetary and non-monetary rewards obtained from fattening; and that credit programmes can benefit the poorer farmers.

TABLE 1. **Average weight gains according to season, 1976/77**

Item	Beginning dry season	Middle dry season	Rainy season
Weight at time of purchase (*kg*)	250	218	195
Weight at time of sale (*kg*)	314	260	283
Weight gained (*kg*)	64	42	88
Length of fattening period (*days*)	106	89	126
Gain per day (*g*)	603	470	696

NOTE: Frequently farmers sold their cattle several days, and sometimes up to one month, after the last weighing. Consequently, the overall weight gained and the length of the fattening period are somewhat understated.

Weight gains. During the first year cattle gained an average of 55 kg over a fattening period averaging 99 days. Daily weight gains averaged 555 g. These weight gains are quite respectable considering that the majority of farmers were fattening cattle for the first time and that the feeding techniques employed were fairly rudimentary. Concentrates, mixed to provide a balanced ration, were not available. Instead, each farmer fed his animal by-products, usually rice bran and sometimes millet bran obtained from his crops. A few bought cotton seed provided by the project.

The above figures mask important seasonal variations in weight gains (see Table 1). During the first year farmers fattened three groups of cattle: the first started at the end of the rainy season, the second began mid-way through the dry season and the third got under way at the beginning of the following rainy season. The differences in average weight gains between each group reflects the availability of forage at different times of the year. Immediately after the rainy season, grass is fairly abundant in the millet fields. As the dry season advances, farmers turn to harvesting a grass called bourgou (*Echinochloa stagwina*), which grows along the banks of the Niger river. By the middle of the dry season this important source of forage begins to dry up as the water level in the river recedes. Unless farmers have made reserves of forage they have difficulty in properly feeding their animals. Once the rainy season is well under way again availability of forage poses no problem. The seasonality of forage availability is also reflected in the weight of cattle at the time of purchase. Cattle bought at the end of the dry season for fattening during the rainy season were very thin indeed.

During the second year further analyses concerning weight gains were undertaken (Table 2). The results are based on the 402 cattle fattened at the beginning of the dry season. The sex of the owner appears to have

TABLE 2. **Average weight gains, by location of village, sex of owner, and type of animal, dry season 1977/78**

Category	Average weight gained (kilograms)
Location of farmers' village	
On river's edge	64
Distant from river	35
Sex of owner	
Female	56
Male	59
Type of animal	
Non-castrated	60
Castrated	48

Cattle arriving for monthly weighing

little effect on the fattening results. Interestingly, non-castrated animals gained considerably more weight than castrated animals. The majority of cattle in this group (78 percent) were not castrated. Finally, farmers living in the five villages close to the river obtained gains that were, on average, considerably above those obtained by farmers living several kilometres from the river.

This last difference can be explained largely by the difficulty small farmers living far from the river had in transporting bourgou from the river to their village. To overcome this problem, the project distributed 35 donkey carts, which were to be paid for over a 12-month period. Similarly, 18 boats were distributed to aid in the harvest of the bourgou.

The generally satisfactory level of weight gains achieved by the farmers can be attributed to several factors: farmers were given general guidelines as to the type of cattle to purchase; all cattle were checked and de-wormed by the project after purchase; each farmer participating in the project was visited every 10 days by an extension worker who gave him advice on feeding and overall care of the animal; all cattle were weighed monthly

to ensure they were gaining weight satisfactorily; and finally, each farmer was initially limited to just one animal.

Profits realized. Net profits estimated from a sample of farmers showed participants in the project making an average of CFAF 9 750 per animal fattened (CFAF 225 = US$ 1 approximately). To have an idea of the relative importance of these profits, it should be borne in mind that the minimum wage fixed for salaried workers by the Government was just over CFAF 10 000 per month.

While weight gains varied according to season, profit level remained virtually constant. Thus, during the first year net profits realized by animals fattened at the beginning of the dry season (end of rainy season) averaged CFAF 9 465 per animal while those fattened mid-way through the dry season averaged CFAF 9 762. The increase in prices (per kg) for finished cattle paid as the dry season progressed and as finished cattle became increasingly scarce more than offset the inferior weight gains registered toward the end of the dry season.

Profits were used by the farmers primarily to buy food, particularly millet, the staple cereal of the Niger, to feed their families. Approximately 66 percent of the farmers used the largest portion of their profits this way.

Response. Initially, participation in the project was modest. Many preferred to wait and see before making a decision. As the first results came in others began to join the project. By the second year the number of cattle being fattened at the beginning of the dry season had risen to 402, compared with 192 in the first year. Farmers began to recognize the opportunity of increasing their overall revenue.

Participation in the project cut across age, sex and, most importantly, economic barriers. Of those fattening cattle with the project, 18 percent were less than 25 years of age, while 16 percent were 50 years or older. Initially participation by the women was very low. By the end of the second year almost 40 percent of all loans were being taken out by

A well-finished animal

women. The poorer farmers participated as much and even more than richer farmers. A survey conducted in the largest village showed that families with an overall revenue below the average for the village had fattened an average of 1.9 animals during the first year and a half of the project. This compares with 1.7 animals for families with incomes above the village average. Since the overall revenue of poor farmers was considerably lower than that of the rich, the impact of the project was more important to their well-being. These figures show that credit programmes need not just benefit those who are already rich.

Repayment of loans. The loans for the purchase of cattle were made to individual farmers on a village-by-village basis. Initially each village chief was responsible for selecting those wishing a loan. Later on this task was passed on to a committee set up in each village to assist the chief. Each village was collectively responsible for loans received by its inhabitants. If a farmer defaulted on repayment of a loan, all new loans to the village were halted until the outstanding debt had been cleared up.

Repayment of loans was satisfactory. During the first year all but CFAF 10 000 of a total of CFAF 14 168 000 lent was repaid. The small sum outstanding was lost when a farmer died before repaying his entire loan. During the second year, repayment, according to the most recent figures, was running at 98 percent for all animals sold. A total of 75 animals were still being fattened.

Conclusions. The experience of the Libore project to date suggests that cattle sold by the nomadic and semi-nomadic herders during the dry season can be finished by small farmers using by-products from their cropping operations. Fattening, in which the live body weight of animals is increased by up to one third over a short period, naturally increases the overall productivity of the livestock sector. The increased production can either be consumed locally or exported. Fattening allows farmers to be gainfully employed during the slack time of the year and to increase their overall revenue. It also provides an important source of organic matter for their crops.

If farmers in the Sahel are to be encouraged to fatten cattle, credit must be made available. A minimum of technical back-up is also required. The first phase of the project at Libore shows the need for finding ways to increase the availability of forage during the dry season. This and other problems will be tackled in the second phase. ■

References

EDDY, E.D. 1975. *Development of the livestock sector in West Africa.* Cornell Agricultural Economics Staff Paper N. 75-17. Ithaca, New York, USA. Cornell University.

HALADOU, S. 1974. Contribution à l'étude de la commercialisation du bétail au Niger. Dakar, Sénégal, Ecole interetats des sciences et médecine vétérinaire de Dakar. (Thesis)

MINISTÈRE DE L'ÉCONOMIE RURALE. 1974. *Rapport annuel.* Niger, Service de l'élevage, Ministère de l'économie rurale.

MINISTÈRE DU PLAN. 1977. *Plan Triennial 1977-80.* Niger, Ministère du plan.

R. Hoogesteijn Reul

Productive potential of wild animals in the tropics

a review of the literature

The current trend of a widening protein gap is most evident in the tropics where the necessary capital and experience necessary to establish an intensive animal industry are lacking and where ecological conditions are not favourable for the usual domestic livestock species (Kay, 1970).

These areas are subject to a series of factors limiting optimum production summarized by Vos (1973) as follows:

- Excessive cost of bush clearing and tsetse control;
- Economically feasible pasture improvement only achieved in higher rainfall areas (+ 700 mm);
- Increased availability of water often resulting in overgrazing in adjacent areas;
- Low protein and energy intakes during the dry season;
- Large numbers of cattle dying during and after major droughts, especially in areas of less than 400-mm annual rainfall and subject to disease and low reproductivity in hot, humid regions.

In temperate countries marginal areas are utilized for wild species that are productive under conditions unsuitable for domestic ungulates. Saiga antelopes (*Saiga imberbis*) in the USSR tundra, which produce 6 000 tons of meat annually (Crawford, 1967), are an example. Red deer (*Cervus elaphus*) and fallow deer (*Dama dama*) are also raised under extensive conditions in New Zealand and Germany (FR) respectively, producing economic returns superior to those from cattle and sheep production (Drew, 1976; Reineken, 1976). In the semi-arid regions of Africa, the age-old cattle-raising practices of native herdsmen, including excessive overgrazing and pastoral burning, are producing desertification. Some native herdsmen who consume mainly the blood and milk of their stock (e.g., the Masai) require from 2.5-4.5 head of cattle per year per person. Vast zones of once-varied fauna and vegetation have already been transformed into spiny-scrub semi-desert resistant to pastoral burning (Kyle, 1972).

The capybara (Hydrochoerus hyrochaeris) *can produce up to 63 kh/ha/year in the flooded grasslands of Venezuela, whereas cattle produce 10 kg/ha/year under present conditions. With controlled densities, the two species do not compete.*

The springbok (Antidorcas marsupialis) *is a small antelope raised widely on farms in South Africa. It is noted for its short breeding cycle.*

Advantages of wild animals in the tropics

Adaptation to heat and drought

The water requirements of cattle limit their grazing range to 5-8 km from a watering point. Certain antelope species such as eland (*Taurotragus oryx*), oryx (*Oryx gazella*), gerenuk (*Litocranius walleri*), Grant's gazelle (*Gazella granti*) and Thomson's gazelle (*G. thomsoni*) can be more or less independent of surface water sources, and are thus able to extend their grazing range. This is because their urine and faeces are highly concentrated. They browse on scrub leaves, from which they obtain moisture. Some graze by night since certain desert grasslands gain in night-time moisture content by as much as 42 percent. They also possess a variable body temperature that can rise as high as 45°C without producing brain damage due to an admirable carotid network in the frontal sinus cavity (Talbot, 1966; Taylor, 1968, 1971).

The author is with the Supplementary Training Programme, Chair of Genetics, Department of Veterinary Sciences, Central University of Venezuela, Apto. 4563, Maracay, Venezuela. The author's thanks are due to D. Plasse, R. Parra, E. Mondolfi and E. González Jiménez for the original bibliographical review.

Domesticated eland and oryx consume only 60 and 25 percent respectively of the water needed by Boran Zebu (*Bos indicus*) cattle, have a wider grazing range and do not degrade water-adjacent areas (King and Heath, 1975).

Resistance to disease

Wild tropical ungulates are generally resistant to diseases, such as trypanosomiasis, endemic in their habitat. They are also more resistant than domestic ungulates to the endo- and ecto-parasitic infestation so widespread in undeveloped areas (Kyle, 1972).

Reproduction

Animal production experts are very familiar with the low reproductive efficiency (RE) of cattle in the tropics. In Africa the interval between births ranges from 591 to 759 days (Skinner, 1967) and RE in the American tropics from 35 to 60 percent (Plasse, 1974). Wild ungulates exhibit the following excellent birth rates: eland, an RE of 85 percent with a 314-day interval between the first and second birth, and thus no stress during the first lactation; African buffalo (*Syncerus caffer*), an RE of 75 percent, despite the fact that the gestation period — 11.5 months — much exceeds that of cattle; wildebeest (*Connochaetes taurinus*), an RE of 95 percent (Sinclair, 1971). Thomson's gazelle and springbok (*Antidorcas marsupialis*) have a rapid population turnover. Sexually mature at 12 months, their gestation period is 16 weeks and offspring are weaned at 12 weeks after birth (Talbot *et al.*, 1965; Skinner *et al.*, 1971).

The female capybara (*Hydrochoerus hydrochaeris*) in the American tropics has 1.5 parturitions per year and averages four offspring per litter. The amount of sexually mature females averages 20-30 percent of the population (Ojasti, 1973). González and Parra (1973) have shown that in the flooded grasslands of Venezuela, the capybara dam produces 6 kg of offspring per year, whereas the cow produces only 1 kg. Age at first conception is 1.5 years for capybara and 3.5 years for cattle.

TABLE 1. **Comparative growth rates for domestic cattle and sheep, and wild ungulates in Central and East Africa**

Species	Average daily gain g	Time months	Average adult liveweight kg	
			Males	Females
Domestic cattle	136	38	453	359
Eland	331	72	725	450
Wildebeest	236	12	200	165
Hartebeest (*Alcelaphus buselaphus*)	227	12	150	120
Topi	199	12	130	115
Domestic sheep	54	10	60	45
Grant's gazelle	118	10	60	45
Impala	118	10	60	45
Thomson's gazelle	59	10	24	18

Source: Adapted from Talbot (1966).

TABLE 2. **Liveweights, carcass weights and carcass composition of some adult East African mammals**

Kilograms

Species	Average liveweight	Carcass weight	Carcass weight as percentage of liveweight	Fat as percentage of carcass weight
African buffalo	753	380	50.5	5.6
Eland	508	301	59.1	4.2
Zebu bull	484	280	58.0	13.7
Zebu heifer	470	271	57.6	28.6
Oryx	176	101	57.0	2.9
Warthog	88	48	54.7	1.8
Grant's gazelle	60	36	60.5	2.8
Impala	57	33	58.1	1.9
Gerenuk	31	20	65.0	2.0
Thomson's gazelle	25	15	58.6	2.0

Source: Adapted from Ledger (1968).

Meat production

Weight gain. Table 1 shows that the average daily gain (ADG) of Grant's and Thomson's gazelles is greater than that of sheep. The ADG of antelope species under extensive conditions in Central East Africa is greater than that of cattle. This is especially true of eland, which reach an adult liveweight of 725 kg with an ADG of 331 g in 72 months. Posselt's eland (1963) reached an adult liveweight of 550 kg for males and 450 kg for females in 4.5 years. Zebu cattle in the same environment (unimproved pasture in arid zones) reached an adult liveweight of 227 kg in 5 years.

Carcass characteristics. Ledger (1968) summarized the carcass characteristics of antelopes and other species of wild African ungulates, such as African buffalo, hippopotamus (*Hippopotamus amphibius*) and warthog (*Phacochoerus althiopicus*), in a table of comparisons that includes domestic cattle. Table 2 summarizes some of these characteristics. The carcass yield for all wild ungulates (except hippopotamus) is greater than for cattle. The average fat content of wild ungulate meat is 3.23 percent compared with 21.15 percent for domestic cattle (data from original table). Weight of hindquarters as percentage of carcass weight and weight of dressed meat were likewise higher in the case of wild ungulates.

The low fat content of antelope carcasses implies that whereas much of the feed consumed by cattle is converted into fat, antelopes convert almost all they consume into meat. Cattle, in order to produce the same

amount of protein as eland, would have to be 30 times as efficient as the eland in terms of feed conversion per body weight (Crawford, 1968). In addition, percentage of carcass yield is virtually constant for wild ungulate species, regardless of age, sex or time of year (Talbot *et al.*, 1965).

Characteristics of the meat. With respect to amino-acid content and proportions, the chemical composition of the meat of wild and domestic ungulates is similar. But fatty composition is very different. In domestic ungulates, lipids are 90-98 percent mono-unsaturated fat, a non-essential energy source. In wild ungulates, lipids are made up of 30-40 percent polyunsaturates — structural fats with a high proportion of phospholipids and rich in the essential fatty acids needed for the building and functioning of the brain (Crawford, 1968, 1973). If proper slaughter practices have been followed (separation of the meat from the hide and guts and adequate bleeding and hanging of the carcass), it is difficult to differentiate the flavour of wild from that of domestic meat.

Utilization of the meat. The different forms of meat from wild animals (dried and salted, fresh, tinned, etc.) comprise 60 percent of Botswana's animal protein intake and is as high as 80 percent in parts of various countries of West Africa (Young, 1973; Crawford and Crawford, 1974). Some 500 and 200 metric tons respectively of wild animal meat are utilized in Uganda and Zambia (Crawford and Crawford, 1974).

Approximately 400 tons of dried, salted capybara are consumed each year in Venezuela. Seasonal variation in carcass yield is very slight, going from 52 percent at the beginning of the dry season to 45 percent at the end. The carcass has a very low fat content. Capybara can produce as much as 63 kg of meat per hectare each year in the flooded grasslands of Venezuela, whereas cattle produce only 14 kg/ha/year (González and Parra, 1973; Ojasti, 1973).

The minimum estimate for blesbok (Damaliscus dorcas) *populations on South African farms is 85 000 head. The rate of stocking is higher than that for cattle.*

Diet, feeding habits, rate of stocking and extraction rate

One major advantage of wild ungulates is that they make use of the full spectrum of available vegetation at different heights off the ground. There are browsing antelopes such as eland and gerenuk which consume the branches and leaves of trees, spiny scrub and brush. There are grazing animals such as the zebra (*Equus burchelli*), African buffalo and wildebeest and there are eaters of roots and tubers such as the warthog and other lesser mammals.

To exclude all herbivores except cattle in an ecosystem with such a range of vegetation is to fail to take advantage of those plant species not consumed by cattle. Four grazers — zebra, topi (*Damaliscus lunatus*), wildebeest and Thomson's gazelle — eat the same grass (*Themeda triandra*) without competing among themselves because each eats a different part of the same plant. When the first three species have removed the different upper parts of the plants, Thomson's gazelle can eat the lower parts along with Dicotyledones which grows in competition with the grass. Thus all species benefit mutually from what has been called a complementary feeding pattern. This has also been demonstrated for other species (Bell, 1971; Talbot, 1966). Morphological differences of the rumen and conformation of the neck, muzzle and tongue allow species such as eland and giraffe (*Giraffa camelopardalis*) to eat tree leaves and spiny scrub. However, the muzzle and tongue of cattle are only adapted to grazing pasture (Hoffman, 1968; Crawford and Crawford, 1974).

The capybara makes use of tough, fibrous forage. Very efficient grinding of forage is achieved by a double set

The eland (Taurotragus oryx) *is the largest antelope. Males can weigh as much as 800 kg. Carcass yield is excellent. Milk production is comparable with that of zebu* (Bos indicus) *cows and the nutrient value of the milk is twice as high. Eland are relatively easy to domesticate.*

of teeth, creating a large surface for caecum bacteria to attack. The caecum holds 75 percent of the digesting matter and is comparable in weight to the rumen and reticulum of cattle (González and Parra, 1971).

The different plant-consumption spectrums of the various species determine their separate ecologies, making possible a higher cropping rate for wild herbivores than for domestic cattle alone in any given area (Talbot, 1966). The higher rate of stocking combined with the higher rate of reproduction and herd replacement generate greater productivity per unit of area without producing devastating effects on soil and vegetation. Under extensive conditions in Kenya, Thomson's gazelle is 17 percent more productive than cattle (Hopcraft and Arman, 1971). Cropping of blesbok (*Damaliscus dorcas*) and springbok in the Transvaal, South Africa, is double that of cattle per km. Such cropping produces an estimated 3 082 kg/km² (Riney and Kettlitz, 1964).

Ojasti (1970) compares the productivity of cattle, capybara and white-tailed deer (*Odocoileus virginianus*) under the extensive conditions of the flooded grasslands of Venezuela. Based on data from his own studies and those of Estrada (1966), he has drawn up a table showing units of biomass with low densities, thus eliminating the possibility of competition for feed (Table 3). The data of Table 3 show the substantial contribution of deer and capybara to the production of exploitable biomass, possibly as much as 48 percent of livestock production with extraction rates higher than those for cattle.

TABLE 3. **Contribution of two wild mammals to the exploitable biomass of the flooded grassland of Venezuela**

Species	Density n/km²	Biomass kg/km²	Net productivity Percentage	Exploitable biomass kg
Cattle	25	7 500	10	750
White-tailed deer	10	400	30	120
Capybara	15	600	40	240
TOTALS	50			1 110

Source: Ojasti (1970).

The biomass of mixed populations in the African savannah ranges from 3 310 kg/km² in Rhodesia to 15 680 kg/km² in Zaire (Ojasti, 1970). These figures exceed the cattle biomass for the same environment by as much as 2 770 kg/km², as is true in Kenya, for example.

Ledger (1968) reports a herd productivity or extraction rate of 17 percent for giraffe and 17 percent for African buffalo. Riney and Kettlitz (1964) give a figure of 50 percent for warthog and 20-30 percent for topi antelope. The Serengeti census (Tanzania) estimates a biomass of 128 kg/ha. Migrations during droughts bring this figure up to 160 kg/ha in certain areas. Adjacent areas used by native herdsmen can carry only 39 kg/ha. Cattle make up 47 percent of the biomass in these areas (Sinclair, 1971).

OTHER USES

In addition to providing meat, wild animals contribute to the economy of African countries in other ways. A good example is Kenya, with its magnificent national parks, where tourism is the country's second most important source of revenue. Tanzania and Botswana also derive substantial earnings from this item. The income from tourism in the Kruger National Park in South Africa now exceeds the potential income from extensive agriculture by about 12 percent. The income from sport hunting in areas adjacent to the Serengeti exceeds proceeds from tourism by 61 percent (Hirst and Catto, 1973; Sinclair, 1971). A number of by-products are also produced for the tourist trade, such as hides and trophies. The trade in such articles is substantial, but little documented. Control is in fact lacking and poaching is rife (Bigalke, 1973).

Milk has been produced experimentally from elk (*Alces alces*) at the Askaniya Nova station in the USSR. Milk productivity is comparable to that of native zebu, but the milk is twice as high in nutrients. Fat content is 9.6-12 percent; non-fat solids 22-23 percent. It has been preserved for as long as eight months at temperatures of 37°C without decomposing taking

on the consistency of edible cottage cheese. This is because of its bactericidal properties, high levels of citric and palmitic acid and low levels of volatile fatty acids. As much as 638 kg of milk have been produced in 207 days, with a fat content of 62.2 kg. The milk also lowers the hyperacidity of human gastric juices and contains cholinesterase fractions that lower blood cholesterol (Treuss and Kravchenko, 1968).

cropping is sometimes undertaken in parks to cull species in areas where overpopulation is causing degradation of the habitat. Among the first commercial experiments was that of Dassmann and Mossman (1961) in Rhodesia. Since that time, a number of similar experiments have been undertaken in Tanzania, Kenya, Uganda, Zambia and elsewhere. Some have been commercially successful, as in the Kruger Park in South Africa,

inspection and hygiene. Some of these problems have been overcome by techniques developed in the Kruger Park. It is a matter of some interest that reports on springbok (Skinner, von la Chevallerie and van Zyl, 1971) and African buffalo (Bindernagel, 1968) populations show a rise in reproductive rates as a result of cropping pressure. On a private ranch in Kenya, 655 Thomson's gazelles and 487 impala (*Aephyceros malampus*)

Wildebeest (Connochaetes taurinus) *in the Luangwa National Park of Zambia, where the Government has taken steps to develop game cropping and conservation, tourist facilities and improved management.*

Utilization of wild animals

The two main methods of utilizing wild animals are termed game cropping and game ranching.

Game cropping. This is a system in which a portion of the herd is selectively cropped based on knowledge of the population dynamics and biology of the species in a given area. The animals are usually shot with high-velocity rifles from blinds, at watering-holes, or at night using spotlights, so that they will not associate hunting with the presence of man. They are then taken to a central area for processing and dressing. Game

the Luangwa Valley in Zambia, and on certain private game ranches in Kenya and South Africa. In the Transvaal in South Africa there are some 3 000 herds of springbok and blesbok being raised in conjunction with cattle. The minimum population estimates for these animals on ranches are 250 000 in the case of springbok and 85 000 in the case of blesbok (Bigalke, 1973).

Other schemes have been unsuccessful for want of proper transport vehicles and marketing facilities (Kyle, 1972). The problems include lack of applied data on census techniques, cropping rates and effective refrigeration, and difficulties with transport,

were cropped over a two-month period; the carcass yield obtained was 18 911 kg, of which only 3.1 percent was condemned as unfit for human consumption (Parker and Graham, 1973).

In Venezuela capybara are rounded up using horses at the close of the dry season. Adults weighing over 30 kg are cropped, excepting pregnant females and those with recent litters. Controlled utilization was begun in 1968 with an extraction rate of 30 percent. Organized capybara ranching still covers a very small area. Many areas have low densities due to poaching. With better utilization of meat and skins — which has now been achieved on an experimental basis —

it is hoped to raise the profit intake per animal. This would stimulate controlled capybara production. At present, only dried, salted meat is consumed. Skins are exported or discarded. (Ojasti, 1970, 1973; Ojasti and Medina, 1972; González, 1972)

Game ranching — domestication of wild animals. Game ranching, still in the experimental stages, utilizes various ungulate species on private ranches with livestock production practices similar to those for cattle. Most promising is the eland because of its adult liveweight (725 kg for males), high carcass yield (59.1 percent), low fat content (4.2 percent) and excellent milk production. Eland breed and survive in marginal areas where cattle die during droughts (Kyle, 1972). Other species with good prospects are Thomson's gazelle, with its short reproductive cycle, and springbok.

It is not suggested here that these animals can replace domestic cattle, but that they can supplement them (Skinner, 1973; Crawford and Crawford, 1974). Some problems that still have to be overcome relate to the marketing of the meat, inter-species competition, fencing costs and poaching. Game-ranching systems have been worked out by expatriate technical specialists and the trained national personnel needed to follow up their work are not available. Governments prefer to see results in the short term, but it will be several years before the economic advantages of these programmes become apparent (Kyle, 1972).

Both systems of livestock-raising entail animal health problems. Wild ungulates, though resistant to local endemic diseases, are susceptible to such introduced diseases as foot-and-mouth and rinderpest. A whole range of diseases and parasites transmissible to man put a question mark after the potential value of wild carcasses. Advances have been made, however, in the use of specially designed darts for the administration of parasiticides and cattle medicines, representing a step forward in the control of unfenced populations (Young, 1973; Kyle, 1972). There is some evidence that intense domestic livestock management with effective disease and predator control (predators are the ultimate hosts of a great range of parasites) also has a positive effect on the health of wild ungulates. This was shown for example by the low incidence of disease on the Kekopey Ranch where an offtake of 300 Thomson's gazelles and 100 Grant's gazelles contained no carcasses that had to be condemned for disease.

One successful game-ranching project in East Africa is the 667 500-hectare Galana Ranch in the semi-arid region of Kenya. The ranch supports 14 000 Boran cattle, sheep, goats, African buffalo, eland and oryx, domesticated and herded by herdsmen from six African tribes. Of this group of animals, the oryx has been especially productive. This is further evidence that the problems of domestication and production of species best suited to a specific habitat are not those of the species involved but of people's attitudes toward them. Many of these wild ungulates were in fact domesticated and used by the ancient Egyptians 5 000 years ago (King and Heath, 1975; King, Heath and Hill, 1977). ■

Zebra (Equus burchelli) *grazing with giraffe* (Giraffa camelopardalis) *in Central Africa. The two species often occur together, a feature that can be taken advantage of in systems of wildlife utilization.*

References

BIGALKE, R. 1973. Technological problems associated with the utilization of wild animals. *III World Conference on Animal Production*. Australia, Sydney University Press. p. 36-46.

BINDERNAGEL, J. 1968. *Game cropping in Uganda*. Kampala, Uganda, Ministry of Animal Industries.

BELL, R. 1971. A grazing ecosystem in the Serengeti. *Sci. Am.*, 225, 1: 86-93.

CRAWFORD, M. 1967. *85th Annual Congress British Vet. Ass.*, p. 1-12.

CRAWFORD, M. 1968. Possible use of wild animals as future sources of food in Africa. *Vet. Rec.*, 82: 305-314.

CRAWFORD, M. 1973. A re-evaluation of the nutrient role of animal products. *III World Conference on Animal Production*. Australia, Sydney University Press. p. 21-35.

CRAWFORD, M. & CRAWFORD, M.A. 1974. An examination of systems of management of wild and domestic animals based on African ecosystems. In *Animal Agriculture*, ed. by H.H. Cole and M. Ronning. Davis, San Francisco, USA, University of California. p. 218-234.

DASMANN, R. & MOSSMAN, A. 1961. Commercial utilization of game mammals on a Rhodesian ranch. *Wildlife*, 3(3): 6-14.

DREW, R. 1976. The farming of Red Deer in New Zealand. *Wld Rev. Anim. Prod.*, 12(3): 49-60.

ESTRADA, H. 1966. *La ganadería en el estado Apure*. Caracas, Venezuela, Council of Rural Welfare.

GONZÁLEZ, E. 1972. Explotación industrial del Chigüire. *Rev. Din. Empres.*, 1(4): 26-28.

GONZÁLEZ, E. & PARRA, R. 1971. *Cinética de los nutrientes en el tracto digestivo del Chigüire. Report 1970-71 on the Chigüire*. Conicit Project DF030.

GONZÁLEZ, E. & PARRA, R. 1973. The Capybara, a meat producing animal for the flooded areas of the tropics. *III World Conference on Animal Production*. Australia, Sydney University Press. p. 81-86.

HIRST, S. & CATTO, G. 1973. Current status and future utilization potential of wild ungulates on natural savanna rangeland in the Transvaal Lowveld, South Africa. *III World Conference on Animal Production*. Australia, Sydney University Press. p. 73-78.

HOFFMAN, R. 1968. Comparisons of the rumen and omasum structures in East Africa game ruminants in relation to their feeding habits. *Symp. Zool. Soc.*, 21: 179-194.

HOPCRAFT, D. & ARMAN, P. 1971. *Preliminary records on comparative productivity of wild and domestic animals. Appendix II. National report on the human environment in Kenya*. 102 p.

KAY, R. 1970. Meat production from wild herbivores. *Proc. Nutr. Soc.*, 29: 271.

KING, J.M. & HEATH, B.R. 1975. Game domestication for animal production in Africa. *Wld Anim. Rev.*, 16: 23-30. Rome, Italy, FAO.

KING, J., HEATH, B. & HILL, R. 1977. Game domestication for animal production in Kenya: theory and practice. *J. agric. Sci.*, 89: 445-457.

KYLE, R. 1972. *Meat production in Africa. The case for some new domestic species*. United Kingdom, University of Bristol. 62 p.

LEDGER, H. 1968. Body composition as a basis for a comparative study of some East African mammals. *Symp. Zool. Soc.*, London, United Kingdom. 21: 289-310.

OJASTI, J. 1970. La fauna silvestre produce. In *Science in Venezuela*. Venezuela, University of Carabobo. 22 p. (Reprint)

OJASTI, J. 1973. *Estudio biológico del Chigüire o Capybara*. Caracas, Venezuela, FONAIAP, Ed. Sucre.

OJASTI, J. & MEDINA, G. 1972. The management of the capybara in Venezuela. *Transactions of the 37th North American Wild. and Nat. Res.* p. 268-277.

PARKER, I. & GRAHAM, A. 1973. Commercial use of Thomson's gazelle and impala on a Kenya beef ranch. *III World Conference on Animal Production*. Australia, Sydney University Press. p. 109-118.

PLASSE, D. 1974. Sistemas genéticos para mejorar la producción de carne en el trópico. In *Potencial para aumentar la producción de carne en América Tropical*. Cali, Colombia. CIAT. 21 p.

POSSELT, J. 1963. The domestication of the eland. *Rhod. J. agric. Res.*, 1: 81-89.

REINEKEN, G. 1976. Nützung von Öd und Grünland durch Damtiere. *Der Tierzüchter*, 12: 560-563.

RINEY, T. & KETTLITZ, W. 1964. *Mammalia*, 28: 128.

SINCLAIR, A. 1971. Wildlife as a resource. *Outlook on agriculture*, 6(6): 261-266.

SKINNER, J. 1967. An appraisal of the eland as a farm animal. *Anim. Breed. Abstracts*, 35: 177-186.

SKINNER, J., CHEVALLERIE, M. VON LA & ZYL, J. VAN. 1971. Appraisal of the springbok for diversifying animal production in South Africa. *Anim. Breed. Abstracts*, 39: 215-224.

SKINNER, J. 1973. Technological aspects of domestication and harvesting of certain species of game in South Africa. *III World Conference on Animal Production*. Australia, Sydney University Press. p. 119-125

TALBOT, L. 1966. *Wild animals as a source of food*. US Department of the Interior, Washington, DC, USA.

TALBOT, L., PAYNE, W., LEDGER, H., VERTCOURT, D. & TALBOT, M. 1965. *The meat production potential of wild animals in Africa*. Farnham Royal, Bucks,. United Kingdom. Tech. Comm. 16. Comm. Bur. An. Breed. and Gen.

TAYLOR, C. 1968. The minimum water requirements of some East African bovids. *Symp. Zool. Soc.*, 21: 195-206.

TAYLOR, C. 1971. Ranching arid lands: physiology of wild and domestic ungulates in the desert. *Proceedings of the Conference on Sustained Production from Semi-arid Areas, October 1971, Gaberone, Botswana*.

TREUSS, V. & KRAVCHENKO, D. 1968. Methods of rearing and economic utilization of eland in the Askaniya Nova Zoological Park. *Symp. Zool. Soc.*, 21: 395-411.

VOS, A. DE. 1973. Wildlife production in Africa. *III World Conference on Animal Production*. Australia, Sydney University Press. p. 67-72.

YOUNG, E. 1973. Technological and economic aspects of game management and utilization in Africa. *III World Conference on Animal Production*. Australia, Sydney University Press. p. 132-141.

Milk production in the tropical lowlands of Bolivia

J.V. Wilkins, G. Pereyra, A. Ali and S. Ayola

The need for an expansion in the Bolivian dairy industry has been detailed by Barrón (1977). He briefly described the three main ecological zones (the high plateau, the valleys and the tropical plains) and stated that the high plateau was probably unsuited to dairying. The temperate valleys at 2 600 m are an ideal environment for milk production with European dairy breeds, but further expansion in the national herd of 10 000 Holstein-Friesians in that zone is hindered by geographical limitations.

The tropical lowlands of Bolivia in the department of Santa Cruz were described in the same paper as having conditions favourable for dairy farming and, under the National Dairy Development Plan, a 240 000-litre/day milk plant has been constructed in the area.

Several herds of pure Holstein-Friesian and pure Brown Swiss cattle have been maintained near Santa Cruz for 20 years. At least two authorities (Ramsden, 1969; Suarez, 1971) have declared the area to be suitable for intensive milk production with Holstein-Friesian cattle using orthodox Western European and North American systems of production. Their studies were based on replies to questions put to individual owners as to what they thought their average milk production, disease incidence and fertility were. No other method was available as no records were kept on any farm at that time. Given the evidence of these reports and the existence of pure herds in the area, plans were made to encourage the importation of female and male cattle of European dairy breeds to replace the existing cattle, the "mestizos". Mestizos are defined in this article as the result of the crossing of zebu and criollo cattle and the random mating of the progeny. Both large-scale farmers, and smallholders from the high plateau who are being settled in colonies on tropical forest land, were to be encouraged to buy imported cows for intensive dairy production.

Visits by the present authors to established dairy farms revealed serious problems connected with maintaining exotic dairy cattle in the Santa Cruz area; it was supposed that the farmers who supplied the data in the studies referred to above had a falsely optimistic idea of the situation.

It seemed possible that farmers would be encouraged to invest in cattle that would not improve the financial position of the individual producer, although the plans would probably increase the daily intake of the milk plant. A similar plan of the Santa Cruz Development Corporation was discarded when model calculations using the planners' optimistic parameters revealed that the farmers' net income would not be increased by a change from mestizo to Holstein-Friesian cattle (Wilkins and Pereyra, 1976).

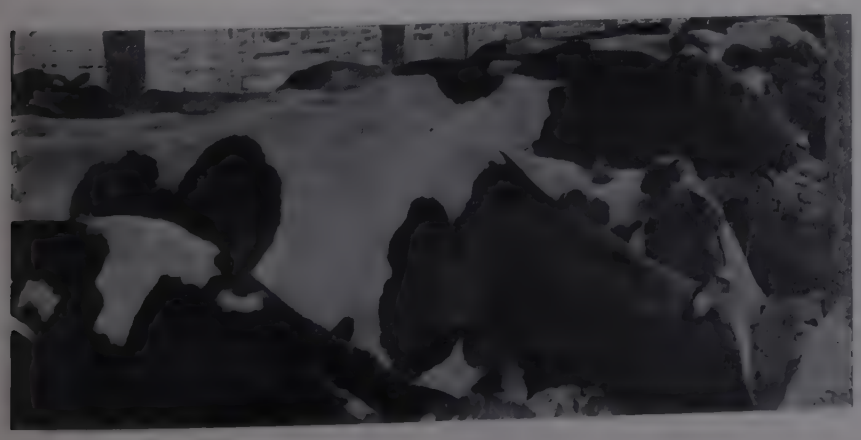
There was evidently an urgent need for parameters of milk production, fertility and mortality on which plans could be based for an expansion in the dairy industry that would be beneficial to both consumer and producer.

The meteorological data for Santa Cruz (lat. 17° 47′ S, long. 63° 10′ W,

In the order listed, the authors' addresses are: Livestock Specialist, British Tropical Agricultural Mission, P.O. Box 359, Santa Cruz, Bolivia; Director, Saavedra Research Station, Livestock Specialist, Records Assistant, Centro de Investigación Agrícola Tropical, Santa Cruz, Bolivia.

Left. *Intensive milk production from Holsteins in shaded yards. Average yield of milk per cow per year is 3 041 kg (System 1).*

Right. *In a very extensive system of milk production (System 6) with criollo/zebu cattle, average yield of milk per cow per year is 183 kg.*



altitude 437 m) for 1977 are shown in Table 1. The effect of high temperatures and humidity is ameliorated by frequent strong winds, but temperature stress in the cool dry season is exacerbated by wildly fluctuating maximum daily temperatures that may vary from 7°C to 32°C on consecutive days.

A programme exists to eradicate brucellosis, foot-and-mouth disease and rabies, but anaplasmosis and babesiosis continue to be endemic.

By-products of the sugar, cotton and rice milling industries are available and cottonseed cake and rice bran are most plentiful during the dry season.

Farmers had used Holstein-Friesian or Brown Swiss bulls on mestizo cattle in crossbreeding programmes. Milk is produced under a variety of systems in the zone, ranging from the maintenance of herds in shaded yards to very extensive systems under which cows are milked once a day in the wet season, when they have milk surplus to the calves' requirements.

It was decided to obtain data on the various breeds and crosses used in the different systems so that the effect of breed and system, and possible interaction of the two on profitability, could be assessed. These data were to be obtained in established dairy herds.

Information on the production, mortality and fertility of exotic cattle during their period of adaptation immediately following their introduction to the new environment was also required. Data for this purpose were to be collected on properties to which cattle were being imported.

Pure Holsteins on Farm No. 123 gave 2 380 kg of milk per cow per year.

Material and methods

Performance on established dairy farms

A small livestock-production recording scheme was established with 26 farms and all cattle were individually identified by ear tags. Three farms subsequently withdrew from the programme; a further four farms situated in the mesothermic valleys are not included in this study as they have a totally different environment to that on all the other farms.

Milk yields were measured monthly by the authors and calving dates, lactation termination dates, deaths, abortions, sales, purchases of stock, feed, drugs and vaccines were recorded by the owner. In the study the causes of death could not usually be ascertained and are thus stated to be unknown. The recorded farms are now the subject of a complementary animal-health study currently under way.

The farms were selected on the basis of the following criteria:

- Degree of cooperation of the owner
- Type of cattle
- Type of system

All the farms had the same climatic environment, and soil differences were not great.

The popular measure in Bolivia of cow production is "litres of milk produced/cow/day", which is subject to various interpretations. In this study "yield of milk per cow per year" is used. This has as its components lactation yield, lactation length and calving interval and provides an immediate basis for economic comparison of the productivity between herds of different lactation yield, persistency and fertility. It also has the advantage that it can be obtained in 365 days whereas average lactation yield, average lactation length and average calving interval could not be obtained in the first 18 months of the programme.

"Yield of milk per cow per year"

TABLE 1. **Meteorological data of Saavedra Station, Santa Cruz, 1977**

Month	Rainfall (mm)	Average daily humidity (Percentage)	Mean daily temperature	
			Minimum	Maximum
			(°C)	
January	437.2	82.6	22.0	29.5
February	92.5	78.0	21.2	31.1
March	119.4	79.3	20.9	29.8
April	74.6	77.5	18.9	29.3
May	6.8	74.8	15.8	27.0
June	19.7	73.4	15.8	27.8
July	16.1	72.8	18.0	28.4
August	122.6	66.2	15.2	27.9
September	29.9	65.0	18.3	30.6
October	52.0	62.1	19.1	32.1
November	211.5	77.9	21.1	30.5
December	71.0	77.8	21.7	30.9
Total	1 253.3			
Mean	104.4	73.95	19.0	29.58

First cross Holstein/mestizo cattle on Farm No. 123 gave 2 744 kg of milk per cow per year. These two photographs illustrate the relative adaptability of the two genotypes in the environment of System 2. The two genotypes had separated in the paddock of their own accord.

was obtained for all cows that were on the farms for the same 365 days. Heifers that calved down for the first time after the recording year commenced are not included, nor are cows that were purchased or sold during the period.

Recording continued for 548 days and the estimated average calving interval was calculated from the following formula:

$$\text{Estimated calving interval} = \frac{548 \times A}{B},$$

where A = number of cows on the farm throughout 548 days, and B = number of calvings of the same cows in the 548 days.

The systems identified in the study are as follows:

System 1. The cows are maintained permanently in shaded yards, receiving cut fodder from improved pastures and forages. They are fed concentrates and are milked twice a day. The calves are weaned from their mothers in the first week of life;

System 2. The cows graze improved pastures and forages, are fed concentrates and are milked twice a day. The calves are weaned from their mothers in the first week of life;

System 3. As in System 2, except that the cows are milked once a day and suckle their calves until the end of the lactation;

System 4. The cows graze improved pastures and forages and do not receive concentrates. They are milked twice a day and the calves are weaned from their mothers in the first week of life;

System 5. Feeding regime as in System 4. The cows suckle their calves and are milked once a day when they have milk surplus to the calves' requirements;

System 6. The cows graze indigenous pasture, do not receive concentrates and are milked once a day when they have milk surplus to their calves' requirements.

TABLE 2. **System, yield, fertility and mortality**

System [1]	Farms (No.)	Cows (No.)	Mean yield of milk/cow/year with standard error (kg)	Estimated average calving interval (days)	Calves born (No.)	Calf mortality (Percentage)	Adults (No.)	Adult mortality (Percentage)
1	2	84	3 040.7±123.4	416.7	152	5.3	114	3.5
2	4	185	2 412.4± 60.2	434.1	239	16.3	221	1.8
3	2	151	1 668.5± 56.7	421.2	275	10.9	193	1.6
4	1	35	1 949.7± 56.7	368.7	68	26.5	47	0
5	5	222	529.4± 28.0	579.0	186	18.3	292	5.1
6	5	56	183.2± 18.2	411.0	76	7.9	69	2.9

[1] See above for definitions of systems.

Production immediately following importation

Four farms that were importing European dairy cattle were recruited into a recording programme. All the cattle were individually identified with ear tags and their milk yields were recorded monthly. The owners recorded calving dates, lactation termination dates, abortions and deaths.

The results obtained on a Government experimental station in the area that had imported cattle four years previously are also included in this data group. Data given in this article refer to the first two years of operation, until the station went into liquidation.

Results

Performance on established farms

System, production, fertility and mortality. The production data of all the farms in the study are shown in Table 2 and indicate the expected high correlation between intensity of system and yield of milk.

The mean yields of milk/cow/year within farms have large variations (standard errors). Systems 2 and 3 have the same grazing and feeding regime and it is estimated that, in System 3, the calves consume approximately 700 kg of milk per cow per year. If the mean yields of the two farms in System 3 are adjusted upward by 700 kg to include this calf consumption, the mean farm yields of milk/cow/year for the six farms are: 2 509.4 kg; 2 430.0 kg; 2 406.9 kg; 2 276.7 kg; 2 208.0 kg; and 2 442.9 kg.

This similarity is surprising because the skills of the individual farmers vary considerably and some feed higher levels of concentrates and make higher quality forages available for their cows. For example, the nutritional status of the cows on the third farm is optimal but average yield is not superior to that on the other farms.

The cows on the two farms in System 1 have higher yields than those in System 2, though their feeding levels are lower than those of the third farm. It may be postulated that their superior yields are in response

TABLE 3. **Breed, yield, fertility and mortality**

System [1]	Breed	Cows (No.)	Mean yield of milk/cow/year with standard error (kg)	Estimated average calving interval (days)	Calves born (No.)	Calf mortality (Percentage)	Adults (No.)	Adult mortality (Percentage)
1	Holstein	84	3 040.7±123.4	416.7	152	5.3	114	3.5
2	Holstein	79	2 402.9± 75.2	470.4	91	23.1	103	6.8
	Brown Swiss	82	2 348.1± 95.0	403.2	106	16.1	104	2.9
3	Brown Swiss	43	1 470.0±122.0	407.8	88	14.8	78	1.3
4	Brown Swiss	35	1 949.7± 56.7	368.7	68	26.5	47	0
5	Holstein	17	543.4± 97.8	514.0	12	41.7	23	13

[1] See page 27 for definitions of systems.

to the provision of shade and to protection from the blood loss and irritation caused by tick infestation.

The mean yield of milk/cow/year of the single farm in System 4 is close to the maximum to be expected from cows grazing tropical pastures unsupplemented by concentrates.

The farms in Systems 5 and 6 contain cows that did not give any milk or that had extremely low yields either because they had little or no milk surplus to the calves' requirements or because they could not be milked for reasons of temperament, or because the premature death of their calves resulted in an immediate termination of the lactation. The performances of all the cows on the farms, including those with zero milk yields, are included in the means.

The correlation between intensity of system and milk production is not repeated in the case of fertility and great variations occur between farms within systems. Nevertheless, the fertility among cows in System 5 is generally low. All the farms in System 6 are small and the superior fertility and lower mortality in that system compared with System 5 are probably due to differences in herd size and the effect of owner management.

One of the components of "yield of milk/cow/year" is fertility. In System 1 and System 2 good persistency compensates for the low fertility of the cows in two herds, so that long calving intervals have not depressed the annual yield of milk below that of more fertile herds in the same system.

Calf mortality in the protected environment of System 1 was expected to be low, but four of the six adult deaths were caused by anaplasmosis. Cattle in this system that are not frequently challenged by tick infestation are likely to lose their natural or induced immunity to tick-borne disease and are, therefore, at a great risk when infected ticks are introduced in the forage or bedding.

Systems 2 and 4 have similar calf-rearing systems and all the farms have a calf mortality of over 12 percent.

In System 3, where the dams suckle their calves, the average calf mortality is a little lower than in other systems, as would be expected.

In extensive Systems 5 and 6, the variations in calf mortality between farms is very high and must indicate the existence of a disease nucleus on some farms or grave deficiencies in calf management.

TABLE 4. **System, crossbreeding, production, fertility and mortality**

System [1]	Farm identity number	Breed or cross	Cows (No.)	Mean yield of milk/cow/year with standard error (kg)	Estimated average calving interval (days)	Calves born (No.)	Calf mortality (Percentage)	Adults (No.)	Adult mortality (Percentage)
2	123	Holstein	20	2 380.2± 90.2	379.4	30	20.0	26	15.4
		Holstein cross mestizo	11	2 744.3±245.9	354.6	21	9.5	17	0
	221	Brown Swiss	17	2 095.2±170.1	394.2	36	22.0	34	2.9
		Brown Swiss cross mestizo	14	2 582.5±336.0	502.3	25	12.0	17	0
3	241	Brown Swiss	11	915.6±184.7	398.5	19	15.8	14	7.1
		Brown Swiss cross mestizo	24	1 557.7±137.0	342.5	58	5.2	51	0
	141	7/8 Brown Swiss	32	1 660.6±137.5	411.0	69	14.5	64	0
		1/2 and 3/4 Brown Swiss	80	1 774.5± 67.3	394.3	126	10.3	126	1.6
5	341	Holstein	17	543.4± 97.8	514.0	12	41.7	23	13
		Holstein cross mestizo	21	838.9± 65.4	480.3	16	18.8	19	5.3
	242	1/2 and 3/4 Brown Swiss	5	1 167.2± 69.0	365.0	5	0	12	0
		Gir	8	375.3±144.7	414.8	12	16.7	22	4.6
	462	1/2 Brown Swiss 1/2 mestizo	18	632.9± 91.7	410.1	12	0	18	0
		Mestizo	15	525.1± 75.8	544.8	10	0	15	0

[1] See page 27 for definitions of systems.

TABLE 5. **Calf mortality on Farm 341**

Breed or cross	Mortality (Percentage)
Mestizo	11
1/2 Holstein	19
3/4 Holstein	29
Holstein	42

System, breed, production, fertility and mortality. The production results of pure Holstein and pure Brown Swiss cattle are shown in Table 3.

Farm No 141, in which criollo cattle have been upcrossed with imported Brown Swiss semen.

Superior farmer-owned criollo cow permanently tethered and fed only crop residues and kitchen waste. This cow is seven months after calving and yielded 6.5 kg of milk at the morning milking.

Unfortunately, both Holstein-Friesian and Brown Swiss cattle are only represented in System 2.

The use of imported cattle in extensive System 5 is obviously uneconomic and the data are included for information only.

There are no statistical differences in production between breeds in System 2 and there is no indication of a tendency for one breed to be superior in milk production in this environment. The fertility of the Holsteins and Brown Swiss can only be compared in System 2, where the estimate suggests that the Brown Swiss are more fertile.

In the protected environment of System 1, the calf mortality of the Holsteins is low, but in System 2, 21 of the 91 Holstein calves born died before reaching six months of age (23 percent). In Systems 2 and 4, which have the same calf-rearing system, 20 percent of the 174 Brown Swiss calves died, but only 15 percent of the 74 Brown Swiss calves that were suckled by their mothers died in the first six months of life.

System, crossbreeding, production, fertility and mortality. Data from farms that have both purebred exotic dairy cows and crossbred cows are shown in Table 4. The differences between breed and cross within farms are not statistically significant but it should be noted that in every farm the average production of the crossbreds is superior to that of the purebreds. There is no indication that pure European dairy cows give more milk per year than crossbred cows in the environments of Systems 2 and 3. In the extensive System 5 crossbreds appear to be superior to pure Gir and "pure" mestizo cows.

With the exception of Farm 221, the crossbred cows are more fertile than the purebreds. The calf mortality of the crossbreds is significantly lower (at the 0.01 percent level) than that of the purebreds, and the adult mortality is also significantly lower (at the 0.05 percent level).

On one farm using System 5, all the calves are 3/4 Brown Swiss out of F_1 Brown Swiss cross mestizo cows. The high calf-mortality of 34.3 percent found there shows that crossbreeding itself will not result in low calf-mortality if there is a strong disease challenge and management is poor. However, the data indicate that the mortality of crossbred calves will be lower than that of purebred calves on the same farms.

Data obtained on Farms 341 and 141 are shown in Tables 5 and 6. These differences are not significant because of the low numbers. Nor are those shown in Table 6 in a herd upcrossing from criollo to Brown Swiss by artificial insemination.

TABLE 6. **Performance of cattle on Farm No. 141**

Item	Brown Swiss blood		
	50%	75%	88%
Number of cows	20	50	32
Mean milk yield/cow/year (*kg*)	1 819.7	1 736.7	1 660.6
Coefficient of variation (%)	45	30	47
Cows calving in year (%)	85	78	75
Calf mortality (%)	7	8	15

The importation of dairy cattle to a tropical environment

The information given below is meant neither to be derogatory of the livestock owners concerned nor is it suggested that all of these losses are unavoidable. It indicates what happened in five situations, where professional consultants actively encouraged

the importation of adult females onto properties that were thought to be sufficiently developed to receive them.

Farm A. 35 Holstein cows were imported in 1975; 18 cows and 8 calves died within 15 months of importation. The surviving 17 cows had an average lactation yield of 507.3 ± 91.4 kg in 191.9 ± 27.3 days. The herd and farm have now been sold.

Farm B. 190 Holstein cows were imported in 1976 and 40 cows and 18 calves died in the first 12 months of operation. The maximum average daily milk yield per cow was 3.5 kg. The herd and farm have now been sold.

Research station C. 82 Brown Swiss cows were imported in 1972. None of the calves born in the first two years survived to over six months of age. Six adults died in the first year. None of the cows yielded sufficient milk to justify milking in their first lactations.

Farm D. 120 Holstein cows were imported in 1976 and in the first 18 months six cows died, nine aborted and calf mortality was 26 percent. 127 lactations have been completed with an average lactation yield of 2 245.8 ± 68.7 kg in 316.1 ± 7.3 days. Estimated average calving interval is 663.6 days.

Parastatal farm E. A herd of 72 pregnant Brown Swiss cows was imported in December 1976 and the herd has been under the constant care of a livestock specialist and veterinarian. The cows were kept in shaded yards and the calves were housed in individual boxes. Three cows died, four cows were sold for slaughter, three cows aborted and 11 percent of the calves born alive died in the first 12 months of operation. 38 percent of the lactations were shorter than 200 days. Average first lactation milk yield was 1 722.2 ± 127.1 kg in 259.4 ± 15.2 days. Mean first calving interval was 490.0 ± 17.6 days. 60 calves have been born in the second calving and 27 have died to date.

A herd of 50 Holstein heifers was imported to the same institution in June 1977 and these were also kept in shaded yards. 47 of these heifers were pregnant and 14 of them aborted within three months of arrival. Seven of these abortions are attributed to an immunization programme. Eight calves died within six months of the importation, so that 47 percent of the calves imported *in utero* did not survive. The mean first lactation yield for 41 of these animals was 3 585.5 ± 320.1 kg while first calving interval will exceed 530 days. Of the 50 calves born alive in this herd 15 have died to date.

A further 70 Holstein cows were imported of which four died in the first nine months. Of 65 calves born alive to date 25 have died.

A final importation was made of 77 Brown Swiss cattle from the United States. In the first four months one cow died and, of 56 calves born alive, 25 died.

Since the project started 24 months ago a total of 301 calves were born alive. Of these, 100 have so far died in spite of skilled and energetic veterinary attention.

The upcrossing programme on Farm 141 . . .

Discussion

The authors are very grateful to the farm owners, who cooperated in providing data during the critical period following importation of female cattle of European dairy breeds into this tropical environment, as information of this type is understandably, but regrettably, rarely published. When data are published the real situation frequently has to be inferred.

. . . produced F_1 Brown Swiss/criollo cows like these.

We have questioned all the owners of long-established herds of pure exotic cattle and all agreed that they had very heavy losses immediately following importation and, with one exception, all were only able to survive the financial losses incurred by returns from other enterprises.

After a period of adaptation, the maintenance of the cows in shaded yards will tend to result in a higher level of production than that obtainable if the cows graze identical forages in the field. Under both systems the costs of milk production using imported cows at their present price are greater than the gross income possible.

Cows with mestizos as mothers and high-quality Holstein or Brown Swiss bulls as fathers do not yield less milk than imported females; they tend to be more fertile and have significantly lower calf and adult mortality. The female progeny of these F_1 cows show a similar performance. This is in agreement with findings in India (Amble and Jain, 1967), East Africa (Meyn and Wilkins, 1974; Kimenye, 1973), and Colombia (Rubio, 1976), and findings reviewed by Mason (1974).

The large-scale importation of female cattle of European dairy breeds for milk production should not be encouraged. However, a limited importation could be recommended for the purpose of forming nucleus herds to produce high-quality bulls for cross-breeding programmes. A person with a herd of mestizo cows would find it more financially advantageous to upcross the cows with a Holstein or Brown Swiss bull of high quality than to sell them and buy imported cows, even if these cows have already passed through the adaptation period. A person with no cattle who wishes to start milk production would find it financially most advantageous to buy mestizo heifers from the ranching areas and commence upcrossing with a high-quality bull of a European dairy breed.

3/4 Brown Swiss/1/4 criollo cow on Farm 141

As mentioned earlier, the milk yields that are being obtained from imported Holsteins are so low that the cost of production per litre of milk is higher than the milk price. The mean yield of milk/cow/year in a herd would have to be higher than the average yield of recorded Friesian herds in the temperate climate of the United Kingdom before it becomes economic. It is probable that methods will be devised for individual cows to achieve this, but the authors believe that it will not be practicable for the great majority of milk producers in the foreseeable future.

A yield of 2 300 kg cow/year is evidently a practicable target-yield in this environment and can be achieved with crossbred cattle. Such cattle can produce this quantity of milk when fed tropical forages that are easy to cultivate but unsuitable for very high-yielding cows. Chopped whole sugar-cane is fed on the majority of dairy farms in the area in the dry season, but this crop could not form the basis of a feeding regime for high-yielding cows. While some specialized pastures will have to be grown, the feeding of crop residues whose production costs are partially carried by another crop will minimize the production costs of milk. Sugar-cane tops, banana leaves and stalks, cassava tops and *Dolichos lablab* grazed in the maize stover are examples of feeds that could ensure low production costs.

The system of milking the cow and suckling the calf with various degrees of restriction is the traditional way of producing milk in Bolivia and the tropical world. Preston (1977) has made a persuasive case for the retention of this system of milk production in the tropics, which is similar to System 3 of this study. The authors noted on their visits to farms participating in the recording scheme that mastitis is negligible in herds that suckle their calves, while it is a serious disease in herds where the calves are not suckled. This was also demonstrated by Preston and Urgate (1972). Calf mortality also tends to be lower when the calf is suckled, though the difference was not found to be statistically significant and was lower than expected. However, the milk:beef price ratio in Bolivia is very narrow (1:4.9) and the value of the male weaner is lower than the value of the 700 litres of milk it consumes when suckled. The gravest disadvantage of the restricted-suckling system is that when a calf dies after the cow has become accustomed to suckling it, the cow usually dries off immediately. As over 10 percent of the calves born die in the early stage of lactation, there is a great loss of milk that the cows had the potential to yield.

As long as the price of beef remains very low relative to that of milk, it is financially advantageous artificially to rear the female calves and to sell all male calves soon after birth.

On ranches with extensive systems of management that are producing cheese, the high value of the milk produced relative to that of the weaned calf is often not appreciated. Cows on a typical ranch of this type have a fertility of 49 percent, a calf mortality of 8 percent and an annual yield of milk per cow of 340 kg. After the costs of dairying have been deducted this low yield of milk, when manufactured into cheese, is worth three times the value of "the weaner for sale per cow per year". Compared with the breeding of pure beef cattle, very extensive milk production is, therefore, much more profitable so long as the milk:meat price ratio is narrow. The productivity per hectare of the system when the cows graze unimproved pastures is very low and is only suitable for large farms with low land value.

The study has indicated that in Systems 2, 3 and 5 it is advantageous to breed F_1 and 3/4 Holstein or Brown Swiss cross mestizo cows. Data in Tables 5 and 6 suggest that the third generation in an upcrossing programme is less adapted to the environment than the F_1 and the 3/4 and has higher calf and adult mortality.

There appears to be a need for bulls of a breed that is adapted to the environment for use in crossbreeding

A typical 7/8 Brown Swiss/1/8 criollo on Farm 141. Her poor condition reflects the slightly reduced yields, reduced fertility and increased calf mortality of her genotype.

programmes with Holstein or Brown Swiss cows. The breed should have a dairy temperament so that the resultant crossbreds could be milked in the absence of the calf. A campaign for the conservation of the Bolivian criollo has begun with a systematic programme of selection for this characteristic.

Summary

The importation of Brown Swiss and Holstein-Friesian cattle into the tropical environment of the Bolivian lowlands results in high adult and calf mortality, low fertility and low yields in the first 18 months. After this period of adaptation, 84 Holsteins in shaded yards yielded 3 040.7 ± 123.4 kg/cow/year, had an adult mortality of 3.5 percent, a calf mortality of 5.3 percent and an estimated mean calving interval of 416.7 days. The equivalent data for 79 adapted Holsteins and 82 adapted Brown Swiss cows grazing improved pastures supplemented with concentrates were 2 402.9 ± 75.2 kg, 6.8 percent, 23.1 percent, 470.4 days and 2 348.1 ± 95.0 kg, 2.9 percent, 16 percent and 403.2 days respectively. Yields in both systems were too low to be economic.

Crossbred Holstein/mestizo and Brown Swiss/mestizo cattle tended to give more milk than the purebreds, tended to be more fertile and had significantly lower calf and adult mortality.

Because the crossbreds are cheaper than purebreds they produce the same yields at a lower cost and without the high risks involved in importing exotic dairy cattle into the tropics.

The importation of female Holstein or Brown Swiss cattle for milk production is, therefore, not recommended but their importation on a limited scale to form nucleus herds for the production of bulls for crossbreeding programmes should be encouraged.

The majority of milk producers should be encouraged to maintain crossbred herds with a target milk yield of 2 300 kg/cow/year in mixed farming systems. This yield can be profitably achieved when use is made of tropical forages and crop residues. ■

References

AMBLE, V.N. & JAIN, J.P. 1967. Comparative performance of different grades of crossbred cows on military farms in India. *J. Dairy Sci.*, 50: 1695-1702.

BARRÓN, L. 1977. The growth of Bolivia's dairy industry. *Wld Anim. Rev.*, 24: 40-43.

KIMENYE, M.D. 1973. *Comparison of Ayrshire and Sahiwal crossbred cows with Ayrshires on Kilifi Farm, Coast Province of Kenya.* University of Nairobi. 95 p. (MSc thesis)

MASON, I.L. 1974. Maintaining crossbred populations of dairy cattle in the tropics. *Wld Anim. Rev.*, 11: 36-43.

MEYN, K. & WILKINS, J.V. 1974. Breeding for milk in Kenya with particular reference to the Sahiwal stud. *Wld Anim. Rev.*, 11: 24-30.

PRESTON, T.R. 1977. A strategy for cattle production in the tropics. *Wld Anim. Rev.*, 21: 11-17.

PRESTON, T.R. & URGATE, J. 1972. Rearing calves by restricted suckling. *Wld Anim. Rev.*, 3: 28-30.

RAMSDEN, R.O. 1969. *Notes on dairying in Santa Cruz.* 21 p. (Mimeograph)

RUBIO, R. 1976. Ganado costeño con cuernos. In *Manual de Asistencia Técnica No. 21.* Bogota, ICA. 106 p.

SUÁREZ, N. 1971. *La industria lechera en Santa Cruz.* Boletín Técnico No. 8. Santa Cruz, MACA/BTAM. 40 p.

WILKINS, J.V. & PEREYRA, G. 1976. *Some alternative development systems for milk production in San Javier.* 9 p. (Mimeograph)

Goat and sheep production potential in the ASEAN region

C. Devendra

Agriculture in the ASEAN countries (Indonesia, Malaysia, Philippines, Singapore and Thailand) is characterized by its emphasis on intensive crop production. This emphasis is favoured by the nature of the sub-humid to humid tropical ecozone, 80 percent of which receives over 15 000 mm annual rainfall, and which has high temperatures and humidity. Within the intensively cropped areas, small-farmer subsistence agriculture is common and the human population densities are among the highest in the world. Crop by-product feeds are generally plentiful and family labour is available at low cost. Livestock, however, are secondary to the cropping pattern although considerable opportunities still exist for increasing production from them. In the case of the large ruminants, there is over-emphasis on cattle in comparison with buffaloes while small ruminants, whose role and value need to be examined, are neglected. This article is, therefore, concerned with goat and sheep production systems in the ASEAN region and prospects for increasing production from them.

Distribution of goat and sheep populations. Despite the emphasis on cropping, there is a thriving livestock industry in the region. Among ruminants, buffaloes and cattle are numerically the most significant but goats and sheep are nevertheless potentially important (Table 1).

The total populations of goats and sheep in the ASEAN region are 7.9 and 3.4 million respectively, giving a ratio of about 1 : 2. These animals account for about 30 percent of the population of total grazing ruminants. Indonesia possess the largest number of goats and sheep (77.1 and 96.2 percent respectively of the region's total), the goat population being approximately the same as the cattle population.

C. Devendra is Senior Research Officer, Fundamental Research Division, MARDI, Serdang, Selangor, Malaysia. This article is part of an APHCA Consultancy on "The Development of Goats in Asia", and is based on a study by the author in the SE Asian region carried out during October and November 1978. The author is grateful to the Director-General, MARDI, for his approval of and support for the appraisal mission.

The present level of productivity. Goats are important in the region for meat and skin production while sheep are valued for mutton, skins and coarse wool (Table 2). Although some goats are milked, mainly for domestic consumption, sheep are never used for milk production. Both species are valuable for manure production in subsistence agriculture, the manure either being cycled to the land or sold. In view of the large population of both species in Indonesia, 75 to 79

TABLE 1. **Goat and sheep populations in the ASEAN countries, 1977**

Country	Goats		Sheep		Ratio of goats:			
	Thousands	Percentage	Thousands	Percentage	goats	sheep	buffaloes	cattle
Indonesia	6 112	77.1	3 286	96.2	1	0.5	0.4	1.0
Malaysia	377	4.8	46	1.3	1	0.1	0.8	1.1
Philippines	1 400	17.7	31	1.0	1	0.0	3.7	1.7
Singapore	2	—	—	—	1	0.0	1.5	4.5
Thailand	31	0.4	52	1.5	1	1.7	183.3	146.7
TOTAL	[1] 7 922	100.0	[2] 3 415	100.0	1	0.4	1.7	1.7

Source: FAO, 1977.
[1] Represents 3.4 percent of the total population of 232 million goats in Asia. — [2] Represents 1.2 percent of the total population of 282 million sheep in Asia.

The indigenous Kambring Katjang goat of Indonesia, Malaysia and the Philippines.

Indigenous sheep in the Philippines

percent of the total meat produced and 77 to 81 percent of the total skins produced come from this country.

It is significant that milk production in all countries is unrecorded. However, although milk is not produced according to official statistics, significant amounts are produced, particularly from goats, at small-farmer level. This production, while generally inefficient, is valuable from the standpoint of its small but significant contribution to the daily intake of animal protein in the local diet. The important feature of this contribution is that, where goats are kept, there is a consistent daily supply of milk contributing to the nutritional well-being of peasants who, by and large, live very close to the poverty line. Another important point is that milk from cows is not always accessible, or is too expensive, for purchase by small farmers. Under these circumstances goat products from the village dairy become particularly important. It can be argued, therefore, that the development of this aspect of goat production complementary to large-scale dairy development from cattle or buffaloes is justified.

Systems of management. The production of meat, skins and fibre is achieved mainly under three systems of management: tethering, extensive grazing; intensive stall-feeding; and integration with plantation crops (coconut, oil palm and rubber). The latter two systems can be included under the general heading of "integration with cropping systems".

Goat and sheep production systems are based on the pattern of agriculture. Tethering is popular, especially during the cropping seasons and where there is access to waste grazing areas close to the farm. Where double cropping is practised the inadequacy of fallow land necessitates confinement. Under single cropping or dryland cultivation, the fallow — during dry seasons — encourages grazing for a large part of the year. Since double cropping is practised in most parts of the region, intensive feeding under confinement is probably the most common system used.

Although tethering and extensive grazing are common, they vary in relation to the cropping pattern and between locations. In west and central Java, for example, intensive stall-feeding is more common than extensive grazing. Tethering has the advantage over extensive grazing in the control it provides over the animals and in its limited requirement of grazing land, which is not always freely available. Intensive stall-feeding is common within cropping areas in which crop residues such as straw and bran from rice (*Oryza sativa*), vines from field crops such as sweet potatoes (*Ipomoea batatas*) and groundnuts (*Arachis hypogaea*) are available in abundance. In parts of the Philippines, sugar-cane by-products are fed to goats, notably in Negros Occidental.

One of the most consistent and commendable features of animal husbandry is the practice of feeding tree leaves to goats in all countries of the region. This commonly includes the feeding of leaves from cassava (*Manihot esculenta* Crantz), jackfruit (*Artocarpus heterophyllus*) and banana (*Musa* spp.). In Indonesia, turi (*Sesbania grandiflora*) and, in the Philippines, ipil-ipil (*Leucaena latisiliqua* (L) Gillis) are also extensively fed. This practice of feeding goats with tree leaves is, perhaps, the most underestimated aspect of goat management, and merits much more investigation.

Integration of goats and sheep with plantation crops such as coconuts, oil palm and rubber is a method that has not received enough attention. It has, however, considerable potential in all countries in the region, notably

TABLE 2. **Production of meat and skins in the ASEAN countries**

Product	Goat		Sheep	
	Tons	Percentage	Tons	Percentage
Meat				
Indonesia	26 000	78.8	12 000	75.0
Malaysia	1 000	3.0	1 000	6.3
Philippines	6 000	18.2	—	—
Singapore	—	—	3 000	18.7
Thailand	—	—	—	—
TOTAL	33 000	100.0	16 000	100.0
Skins (fresh)				
Indonesia	5 100	76.9	2 400	80.6
Malaysia	144	2.2	147	4.9
Philippines	1 372	20.6	23	0.8
Singapore	4	—	341	11.5
Thailand	31	0.5	65	2.2
TOTAL	6 651	100.0	2 976	100.0

Source: FAO, 1977.

Indonesia, Malaysia and the Philippines. Limited development of the method may be associated with the fact that there is concern over possible damage to trees; however, with proper control and regulation of animal numbers to available herbage, this should not be a problem.

Ownership. Goats and sheep are owned mainly by small farmers or landless peasants. In the case of small farmers in all of the countries (with the exception of Singapore), the flocks are found (20 to 70 goats) including one or two large units of some 200-400 goats each.

Characteristics of small farming. One important distinguishing feature of the ownership of goats and sheep in the ASEAN region, and in most parts of the humid tropics, is that they are owned by small farmers. Development programmes that are directed at increasing the contribution from goats and sheep must therefore take cognizance of the characteristics

Typical housing on stilts for sheep and goats in the Philippines.

percentage of goats and sheep of total livestock on farms of less than 2 ha is in excess of 90 percent. This in itself suggests that small flocks only are common, and hence that, with very few exceptions, small-scale subsistence production is typical throughout the region.

Table 3 summarizes information on size of flocks in small-farmer units usually intensively cropped — in individual countries, based on extensive surveys and discussions. The statistics refer specifically to private owners. Large flocks are few and uncommon and even these usually consist of no more than about 20 to 50 animals per farm in Indonesia, Malaysia and Thailand. The largest goat flocks in Malaysia consist of about 200 head. In the Philippines, however, larger

of small-farmer goat and sheep rearing in the ASEAN region. These are:

- The small farmers are essentially crop-oriented subsistence farmers with low incomes living close to the poverty line;
- Rearing goats and sheep involves minimum management attention, is a source of investment, has low risk and provides a specific source of supplementary income;
- Goats and sheep provide a source of meat, some milk, skins and fibre. In addition, they serve a variety of valuable miscellaneous functions such as insurance against crop failure and in the production of manure;
- The small farmers may, or may not, possess cattle and/or buffaloes (in any case not more than one or two head) but most, invariably, possess goats or sheep or both;
- In an agricultural environment that is predominatly crop-oriented, where crop by-products are varied and abundant, the ownership by small farmers of goats and sheep provides a means of converting the residues into useful animal products and this constitutes an important component of efficiency in the use of existing resources.

TABLE 3. **Average flock size of goats and sheep owned by smallholders**

Country	Average size of land area (ha)	Size of flock	
		Goats	Sheep
Indonesia	1.0	4-5	3-5
Malaysia	1.0	3-4	2-5
Philippines	1-3	4-8	2
Thailand	2-4	4-9	3-8

Goat and sheep husbandry. Goats and sheep are usually reared separately, owing to the preference of the farmer for one species. When they are grazed, however, there is a tendency to run them together, herded usually by children. Invariably bucks or rams are owned, irrespective of the size of the flock. In almost all cases the number of males is much higher than necessary; for example, in a flock of four to six breeding females, it is not uncommon to find one to two males.

Depending on the system of management practised, goats and sheep are allowed to graze or are fed on cut grasses and tree leaves. Given the small flocks characteristic of the region, there is very little special cultivation of grasses. The grasses that are fed thus come from uncultivated, waste grasses, such as cogon (*Imperata cylindrica*) in Indonesia and Malaysia. In the larger units found in the Philippines and Malaysia, grasses such as Guinea (*Panicum maximum*) and Napier (*Pennisetum purpureum*) are cultivated, harvested and fed to goats, Very seldom, however, are these grasses cut at the right stage of growth or chopped prior to feeding. The residual wastage is, therefore, high.

In the case of goats, as was previously mentioned, a variety of tree leaves are fed. In west Java, Indonesia, this system is of particular im-

portance. There, goats or sheep are fed intensively in confinement, farmers taking great pains to collect the leaves for feeding. Indeed, even in the peri-urban areas, farmers walk considerable distances (up to 2 km) to harvest leaves from, for example, the jackfruit tree (*A. heterophyllus*). Only small amounts of concentrate by-products such as copra cake are fed, partly because of their limited availability but also because farmers do not know how to use them in feeding systems. Although purchased concentrates are seldom fed, salt is commonly given.

Goats and sheep are often housed. The design of such housing varies, but all houses are invariably on stilts and have a trough space on the outside. They are usually independent of the farmer's home. Wood is very commonly used in the region and bamboo is extensively used in the Philippines. The roofing material, particularly in Indonesia, varies greatly and includes the use of cogon (*I. cylindrica*), attap, bamboo leaves, coconut fronds and even tiles. Where leaves are used as roofing material these are replaced annually.

Animals are sold on the hoof either to neighbouring farmers or to butchers for slaughter. They may also be sold in the cities. In the latter case, farmers are invariably at a disadvantage and are often paid much less than the retail value of the animals.

Diseases are a problem and affect production. Scab is common, but

Goats, mainly from Botangos, at the Qugon market, the Philippines.

internal parasites (mainly Haemonchus) are probably the most serious cause of mortality. Foot rot is uncommon, probably as a result of the use of slatted floors.

Demand for meat exceeds supply. Throughout the region, goat meat in particular and, to a lesser extent, mutton are relished. In parts of Indonesia and Thailand, mutton is in great demand. Demand far exceeds supply, with the result that meat prices are very high and continuously rising. Indeed, the situation is such that the price of goat meat is high relative to other meats sold in the market. In Malaysia, for example, the price of goat meat, at around US$ 3.4 to 4.0 per kg (1979), is higher than all other meats. Similarly, in the Philippines, a combination of demand for goat meat and a shortage of breeding animals is reflected in the relatively high price charged: around US$ 20 to 30 for goats weighing about 10 kg.

The reason for this state of affairs, as regards the goat, is the negative population growth of this species coupled with high off-take rates. A negative growth for both species is also partly due to the over-emphasis on cattle production. Table 4 shows that, with the exception of Malaysia and the Philippines, all countries recorded a negative growth (Table 4). In practice this means that there has been excessive slaughter of breeding animals in rural areas, concurrent with a continuous reduction in the age at slaughter. If this trend is not arrested the national flock will be depleted. This situation has prompted the import of sheep, mainly from Australia, which has been increasing to provide a substitute for goat's meat. In 1977, for example, approximately 130 000 live sheep were imported into Singapore for this purpose, the meat of which was also sold on the Malaysian market.

Indigenous sheep in Serdang, Malaysia.

Genetic resources. The region has some quite outstanding goat and sheep breeds. So far, however, inadequate attention has been paid to their development and to the improvement of their productivity. Thus, for example, the Priangan sheep, including the Garut, and the fat-tail sheep are two outstanding sheep breeds in Java, Indonesia, having the important characteristics of a high rate of twinning and high lambing frequency. Similarly, the Kambing Katjang of Malaysia, Indonesia and the Philippines is also very fertile with a high kid-crop and kidding frequency and short interval between kiddings. However, it has poor growth potential (about 55 g per day) so that improving meat production in this breed type may necessitate crossbreeding with, for example, the Anglo-Nubian.

Table 5 lists the breeds of goats and sheep and their main characteristics that merit attention in the region. The scope and technique for genetic

TABLE 4. **Population trends of goats and sheep in the ASEAN countries**
(Thousands)

Species	1961-65	1977	Percentage change
Goats			
Indonesia	7 506	6 112	— 18.6
Malaysia	331	377	+ 13.9
Philippines	561	1 400	+ 149.6
Singapore	2	2	—
Thailand	36	31	— 13.9
TOTAL	8 436	7 922	— 6.1
Sheep			
Indonesia	3 540	3 286	— 7.2
Malaysia	38	46	+ 21.1
Philippines	22	31	+ 40.9
Singapore	—	—	+ 271.4
TOTAL	3 614	3 415	— 5.5

Source: FAO, 1976; 1977.

improvement among the indigenous sheep of Malaysia, and their potential for carpet-wool production, and among other tropical and temperate sheep that might be suitable for the region have been discussed by Turner (1974).

Significance of efficient nutritional management. Of the various environmental factors that limit production, nutrition is by far the most important. The low level of productivity currently evident in goats and sheep is due mainly to a combination of underfeeding, disease and poor husbandry. Goats, for example, have evolved mainly in an extensive and free-range system under conditions of a fluctuating environment characterized to a marked degree by lack of feed. The poverty of the peasants in rural areas also inhibits production from goats and sheep. Where chronic malnutrition is evident, heavy parasitic burdens accentuate the effects of this on productivity. Periods of starvation alternate with intervals of a low plane of nutrition resulting in small size and slow maturity.

Table 6 presents evidence of the significant part played by nutrition in the productivity of goats when attention is paid to ensuring high standards of feeding and management. Of the parameters that were measured, liveweight at slaughter, hot carcass weight, dressing percentage, weight of meat and total saleable weight (Devendra, 1979a) were improved by as much as 53.8, 79.3, 7.1, 47.1 and 34.1 percent respectively, as a result of improved conditions.

The application of more efficient systems of management calls for increased intensification, especially of those avenues of production that offer potential exploitation. The need for such intensification is evident, since availability of land will decrease in the future. An example of intensification that has potential in the region is the integration of goats and sheep with plantation or tree crops and cropping systems. This system is not new — it has been attempted in Sri Lanka, Africa and elsewhere — but the realization that it has economic potential is new (Devendra, 1978a). In the case of goats, there is the added advantage that, with their ability efficiently to digest coarse feeds (apparently higher than that of other ruminants [Devendra, 1978b]), various browse plants and weeds that otherwise would not be used can, under proper control, be utilized.

TABLE 5. **Prominent goat and sheep breeds in the ASEAN region worthy of development**

Species	Breed	Location	Speciality
Goats	Kambing Katjang	Indonesia, Malaysia, Philippines, Singapore and Thailand	Meat, prolificacy
	Kambing Etawah (Jamnapari)	Indonesia	Milk and meat
Sheep	Priangan	Indonesia	Meat, prolificacy, coarse wool
	East Java fat-tailed	Indonesia	Meat, prolificacy, coarse wool
	Indigenous	Malaysia and Thailand	Meat, coarse wool

Potential production of goats and sheep at small-farm level. Increasing the productivity of both species requires high standards of efficiency in the application of the factors affecting production. There are two aspects to such efficient production: full exploitation of the production characteristics (fertility, growth rate, dressing percentage, meat or milk production) of the local goat and sheep population; and the utilization of known technology and development inputs.

Since the bulk of the goats are reared at small-farm level, clearly it is at this level that efforts should be made to encourage the maximization of production from both species. A first question that small farmers are likely to ask is, what is the value of the species? Simple as it may seem, the question is significant, since in most instances there is no definition of production objectives (meat, milk, fibre and skins) or of the characteristics of the product, as for example, the total amount of lean meat in the carcass. Once the objective of production is defined, the next task is to

consider the resources (available and additionally needed) and clearly identify these in an effective production system. The choice of the management system will be largely influenced by the availability of feeds. Large supplies of by-product feeds and potentialities for grass cultivation would, for example, stimulate intensive production. Conversely, their limited production would encourage uncontrolled extensive grazing.

Looking into the future, two management systems seem of potential importance to the small farmer in the region: intensive production on forages and by-products, and small integrated systems of ruminant and crop production. Given the resources, known technology and development assistance available to the small farmer, it is appropriate to discuss both systems and particularly those aspects that merit special attention.

TABLE 6. **Magnitude of improvement feasible in indigenous Kambing Katjang goats from rural areas due to improved nutritional management in Malaysia**

Parameter	Rural goats [1]	Experimental goats [1]	Improvement feasible (Percentage)
Liveweight at slaughter (*kg*)	18.6	28.6	53.8
Hot carcass weight (*kg*)	8.2	14.7	79.3
Dressing (*Percent*)	44.2	51.3	7.1
Weight of meat (*kg*)	5.5	8.1	47.3
Meat:bone ratio	4.1	4.9	19.5
Forequarter (*kg*)	1.2	2.9	108.3
Hind leg (*kg*)	1.2	2.2	83.3
Total edible weight (*kg*)	13.2	18.2	36.8
Total saleable weight (*kg*)	17.9	24.0	34.1

Source: Devendra, 1979b
[1] Adult goats about 3 years of age.

Indigenous buck in the Philippines.

INTENSIVE PRODUCTION. For intensive production of meat, grasses and/or by-product feeds can be used, preferably in confinement. With grasses, both type and quality are important. Guinea grass (*Panicum maximum*) is preferred as a fodder to Napier grass (*Pennisetum purpureum*) because it is more palatable and less coarse, and is usually fed to animals that are about 3-4 weeks old. An adequate intake of dry matter can be ensured by adding tree leaves to the diet.

Very much more use can be made of a variety of abundant by-product feeds in the region, mainly based on cereals, sugar cane, and tree crops such as coconut, oil palm and rubber. The by-product feeds will, however, need to be provided in suitable combinations and should be able to meet dietary needs, particularly of energy and protein. Since concentrate feeding is unavoidable in the case of dairy goats, the same by-product feeds can be used for this purpose. This will reduce the need for (and therefore the cost of) purchased feeds. Where possible, conservation of by-products (e.g., rice straw) is useful, especially during periods of shortage and drought.

INTEGRATION WITH CROPPING SYSTEMS. In regard to the integration of animal husbandry and crop production, the following aspects need to be considered:

- The crop production system (i.e., does the system involve annual crops or tree crops?);
- The availability of feed (dry matter yields of the available herbage and, with crop residues, the quantities available);
- The number of goats or sheep that can be carried;
- The improvement of grazing management.

Indigenous doe with three kids in the Pangasinan Province of the Philippines.

Thus, for example, the herbage undergrowth of rubber and coconut plantations in Malaysia have an annual dry matter production of between 480-500 kg/ha and 800-1 200 kg/ha, with corresponding crude protein contents of about 14-16 and 8-12 percent respectively (Devendra, 1975). On the basis of 3 percent of body weight (20 kg) daily dry matter intake for both species, the equivalent carrying capacity for both crops is two, and four to five animals per hectare respectively.

An initial assessment of carrying capacity is essential since this will determine the size of the operation. In the case of tree cropping, integration involves grazing, whereas with annual crops such as rice or sugar cane, there will be limited grazing and browsing, but with considerable quantities of crop residues available for feeding. It is possible, of course, to combine intensive stall-feeding with the integration process — on coconut plantations, for example, where coconut cake is available as a by-product. In both cases, however, intensive management is essential and this should include the regular drenching of the animals.

Improved husbandry. Improved husbandry at all levels of management is a prerequisite for good animal performance. Parasitic infestation seriously impairs production and needs to be kept to a minimum. This can be done by rotational grazing, as well as by regular drenching.

With the small number of goats or sheep owned per small farmer (Table 3), selection within existing breeds is impossible. The use of either one buck or ram per four to five females is very inefficient, unless there are plans to expand numbers.

Jamnapari goats on a dairy goat farm, Surabaja, Indonesia.

Instead, small farmers can take advantage of good-quality male sires or make use of artificial insemination (AI) facilities at government stations. This approach has the effect of improving the quality of the indigenous animals. Turner (1978) in this connection has discussed "rings" of cooperatives with circulation of rams for small farmers. Increasing production thus assumes that both the quality of the animals and the overall husbandry will be improved.

Support services. Much of what can be done to increase production at small-farm level is dependent to a very large extent on the resources and support services that can be made available to the small farmers. Present evidence throughout the region indicates that both species are given low priority in livestock development programmes and few countries support programmes commensurate with the importance and future potential of goats and sheep. There is, therefore, a need to make available to small farmers greater resources (germ plasm, seeds and fertilizers, credit, research and technology) and extension-oriented support service (marketing, training, field programmes and demonstration centres). Such provisions, deficient in the past, can be substantially increased to stimulate interest in goats and sheep in the region.

Given the resources and technology, it is essential to work toward a planned level of productivity. Aiming for a realistic level of productivity is, therefore, an important component in improving the productivity of goats and sheep. Table 7 presents some important parameters for the Kambing Katjang breed of goats.

TABLE 7. **Parameters of economic importance in the indigenous Kambing Katjang goat breed that can be achieved by attention to improved husbandry**

Parameter	Value
Liveweight increase/day (indigenous) (*g*) [1]	56-65
Liveweight increase/day (crossbred) (*g*) [1]	100-120
Weight of meat (*kg*)	8-9
Fertility (kidding) (*percentage*) [2]	160
Kidding interval (*days*)	40-60
Liveweight at slaughter (adults, $2\frac{1}{2}$-3 years of age) (*kg*)	28-30
Dressing (*percentage*)	48-50
Mortality (annual) (*percentage*)	5

[1] From birth to 12 months of age. — [2] No. of kids born per 100 breeding does.

Strategy for development. The goats and sheep of the ASEAN region constitute an invaluable genetic resource. Various breeds within both species are well adapted to the region, and their value as renewable resources in the production of meat, milk, skin and coarse hair needs to be maintained and increased. In particular, plans for developing these two species need to be strengthened since, in subsistence agriculture, both species play a valuable role in the supply not only of important animal proteins vital to good health, but also in providing an important source of supplementary income.

In the case of goats, the Kambing Katjang and Kambing Etawah (Jamnapari) breeds and, in the case of sheep, the Priangan, East Java fat-tailed and indigenous sheep breeds of Malaysia and Thailand have considerable potential for improvement. In the absence of comprehensive improvement-programmes, the Kambing Katjang is declining in numerical importance in the region, especially in Indonesia and Malaysia, on account of excessive slaughter and indiscriminate crossbreeding with exotic breeds. However, support is being given for the improvement of the Priangan and East Java fat-tailed sheep under the FAO/UNEP project for the *Conservation of animal genetic resources* (Mason, 1978). The importance of small ruminant breeds of the region justifies a thorough study of the characteristics and potentials for improvement of the various breeds and for this purpose the FAO/UNEP project might be expanded to include goats in its terms of reference in view of the significance of this species in the region.

Clearly there is a very real need to increase goat and sheep numbers,

particularly in the face of the negative growth rates shown in Table 4. Since the primary task is to increase the amount of meat produced in the region, there must first be an increase in the numbers of breeding females. It is, therefore, appropriate to consider the factors that contribute to the build-up in numbers of breeding females. These are as follows: age at first mating (females); number of years in the breeding flock; annual mortality rate in the breeding flock; and the number of female young reared to

Four-tooth doe at Togaitan (Batangos), the Philippines.

Indigenous does in Malaysia.

breeding age each year per 100 breeding females. The latter is influenced by the percentage of breeding females failing to conceive; the percentage of breeding females producing multiple births; the frequency of parturition (influenced by durations of gestation and post-partum anoestrus); and the mortality rates in young, from birth to first mating.

The most pressing need is to stimulate existing systems toward increased production, so as to keep pace with the increase in demand. A substantial increase, especially in the goat population, is necessary to offset high off-take rates. This calls for curbs on slaughter, especially of breeding females, and increased production.

In some countries the problem has been recognized and large-scale development programmes have been initiated, particularly in Indonesia and the Philippines. The programme in Indonesia is aimed at increasing the production of goat meat between 1977 and 1983 (Sochadji *et al.*, 1977) through a combination of imports of breeding goats and the improvement of systems of management. In the Philippines the development programme initiated by the Bureau of Animal Industry has as its overall objective the raising of the present level of nutrition of farm families and the achievement of self-sufficiency in goat meat and milk in the *barangays* (villages). The project is complementary to the National Job Generation Programme of the Ministry of Human Settlements, which covers some 30 000 *barangays*. It anticipates that there will be an income generation of about US$ 70 for each family owning two does (Escudero, 1978). In Thailand the King has called for the development of goats in the south. Malaysia has increased the importation of exotic breeds. In regard to the availability of breeding stock, some of the major problems likely to arise concern the sources of such stock, its availability and the means of its transport to where it is required.

Of immediate concern in any development programme for improvement of small ruminants is the need for improved management, nutrition being the major factor in increasing goat and sheep productivity (Devendra, 1979b). This calls for greater information on feed resources, nutritive values and feeding potential. In intensively cropped areas, crop residues are abundant and higher productivity from both goats and sheep would require that these are made use of and fed in suitable combination to ensure high production. Economic production of meat from small ruminants is likely to be achieved by the efficient conversion of cheap, easily available by-products and other materials into meat. Implicit in this approach is the feeding value of tree leaves. These add variety to the diet and have a beneficial effect on goats.

In order to stimulate increased production from goats and sheep by improved feeding and management detailed attention needs to be paid to the following:

- Feed inventories that describe in detail the type, quality and quantity available of various individual feeds. These include crop residues, tree leaves and other native feeds. Information on their feeding value would also be useful;
- Information concerning the feeding value of new sources of forage such as ipil-ipil [*L. latisiliqua* (L) Gillis], turi (*S. grandiflora*) and cassava (*M. esculenta* Crantz);
- The development of appropriate management regimes that would include comparison of both grazing and stall-feeding systems. Little is known, for example, about the value of tree leaves in stall-feeding systems;
- Definition of production systems specific to individual environments that demonstrate both the high production of animals and their profitability.

In all phases of development, documentation at present is inadequate and needs to be improved and strengthened. Such documentation should include detailed data on the performance of indigenous breeds and their crosses and on the economics of production under different management systems.

It has been suggested by Scoville (1976) that the two main constraints facing the small-farmer livestock producer, especially in tropical regions, are inadequate feed supplies and pastures, and poor, or limited exploitation of the possibilities existing in mixed-crop/livestock operations. Clearly, increasing productivity implies overcoming these constraints by enlightened support, sound development-programmes and multidisciplinary problem-oriented research.

Close links between institutions and scientists working with small ruminants are of considerable value, particularly since so little research and development on goats and sheep have been undertaken in the region. Such links need to be developed at the national and regional levels with contributions from different disciplines so as to provide a regional network under which the development of both species can be carried out. Trained manpower is vital for such development efforts.

Indigenous doe in the Philippines.

Conclusions. Although the crop-oriented agricultural pattern is predominant in the ASEAN region, goats and sheep are important farm animals in subsistence agriculture. As a result of the over-emphasis on cattle development, and because of the importance of sheep and goats as a renewable resource and their neglect in the past, both goat and sheep husbandry and production urgently need attention. Rearing goats and sheep, although considered as being of secondary interest, is nevertheless common among small farmers. Both species perform a variety of very useful functions. Priority should, therefore, be given to the development of small-farmer production systems.

Increasing production from both goats and sheep necessitates overcoming constraints to production and aiming at realistic levels of production. This requires concerted and organized efforts by producers, scientists and planners. The problems are of great interest and constraints can be overcome by enlightened support and multidisciplinary problem-oriented research. The strategy for development, therefore, should provide for the most efficient use of the goat and sheep resources of the ASEAN region. ■

References

DEVENDRA, C. 1975. *Goat production on small farms in South East Asia.* FAO Report on Integration of Livestock with crop production at small farm level. Rome, FAO. Vol. 11. p. 176-210.

DEVENDRA, C. 1978a. A model for the integration of goats with cropping systems in the ASEAN region. In *Proceedings from Seminar on Integration of Livestock with Plantation Crops.* p. 84-97.

DEVENDRA, C. 1978b. The digestive efficiency of goats. *World Review of Animal Production*, 14(1): 9-22.

DEVENDRA, C. 1979a. Potential of sheep and goats in world food production. *J. Anim. Sci.* (In press)

DEVENDRA, C. 1979b. Ruminant nutrition and productivity in the ASEAN region. *Seminar on animal health and nutrition in the tropics, 18-23 February 1979.* Townsville, Australia. James Cook University of North Queensland. 38 p. (Mimeograph)

ESCUDERO III, S.H. 1978. *Kambing pangkabuhayan.* Bureau of Animal Industry. Manila, Philippines. 77 p.

FAO. 1976. *Production yearbook 1976.* Vol. 30. Rome, Italy, FAO.

FAO. 1977. *Production yearbook 1977.* Vol. 31. Rome, Italy, FAO.

MASON, I.L. 1978. Sheep in Java. *Wld Anim. Rev.*, 27: 17-22. Rome, FAO.

SCOVILLE, O.J. 1976. *Improving ruminant livestock production on smallholdings.* Agric. Dev. Council Seminar Report No. 11. 12 p.

SOCHADJI, W.D.W., WARKIDI, A., BUDIMAN, S. & GERKGUK, R. 1977. *Ranchangan makrodan mikro kebijaksanaan pengembangan usaha ternak kecil di Indonesia* (1977-1983). Djakarta, Indonesia, Direktorat Bina Progran. Direktorat Jendral Perternakan. 51 p.

TURNER, H.N. 1974. Some aspects of sheep breeding in the tropics. *Wld Anim. Rev.*, 10: 31-37. Rome, FAO.

TURNER, H.N. 1978. Sheep and the smallholder. *Wld Anim. Rev.*, 28: 4-8. Rome, FAO.

The utilization of grains in animal feed

M.B. Dale

Despite considerable improvements in the production of fodder (i.e., pastures, silage and roughages) over the past 20 years, the most impressive growth in the feedstuff sector has occurred in concentrates, particularly of grains and oilseed proteins. The estimated global feed use of grains increased by over 60 percent between 1962-64 and 1977 (Table 1), mainly as a result of the availability of relatively cheap grains, reflecting the increased production of maize, barley and sorghum.

The latest FAO projections[1] point to further appreciable increases in the demand for livestock products between now and 1985. World demand for meat is projected to increase from 108 million tons to 144 million tons between 1972-74 and 1985, while world consumption of milk is expected to rise from 416 million tons to over 500 million tons during the same period (Figure 1).

Over the next five years the combined output of beef, veal and sheep meat is expected to grow at a somewhat slower rate than in the 1960s and 1970s but the production of pig and poultry meat, as well as the output of milk, could continue to grow as rapidly as it has in the past. Hence those sectors of the livestock industry in which the use of feed concentrates — chiefly feedgrains —

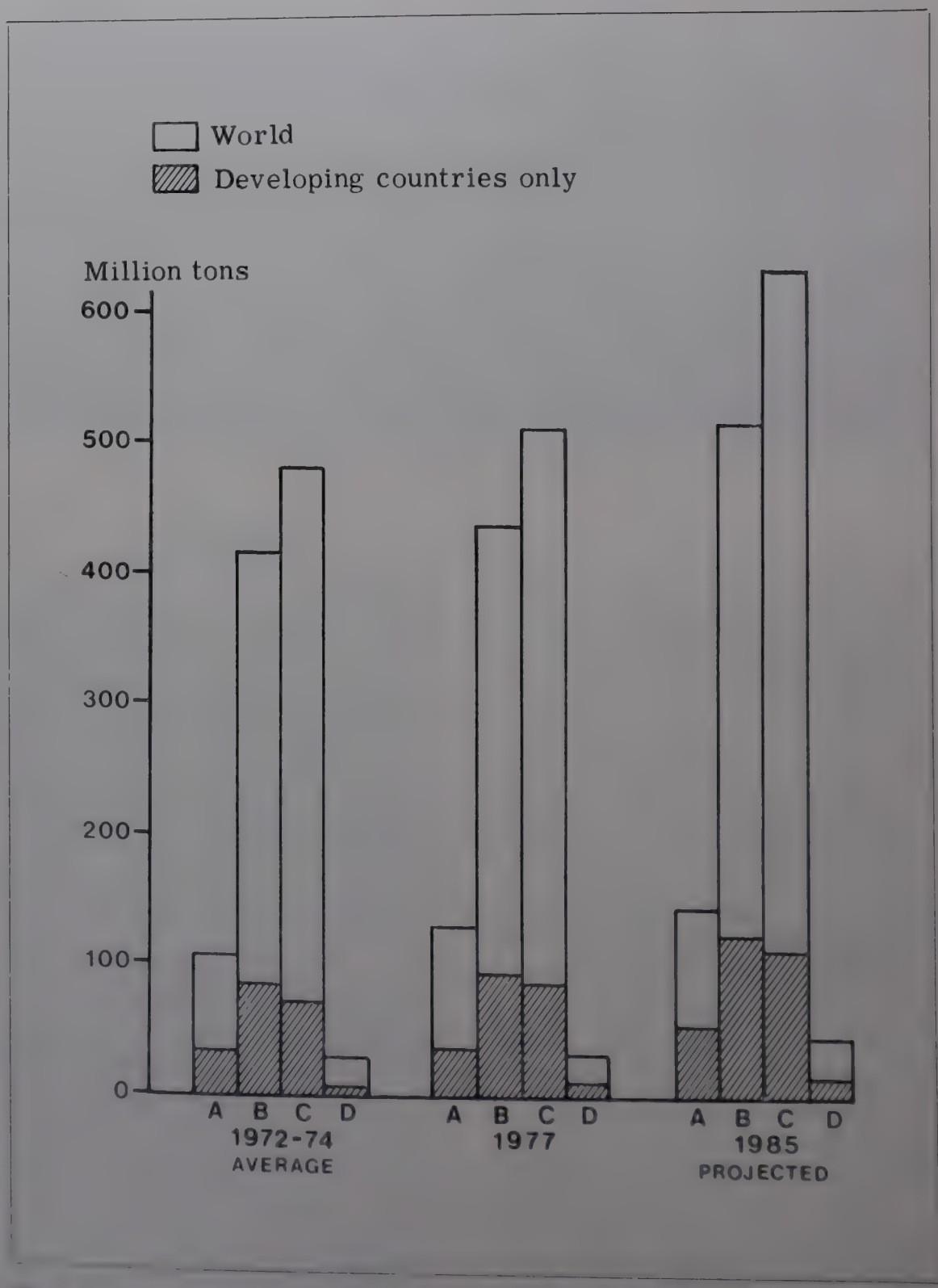


Figure 1. *World demand for meat, milk, grains used as feed, and oilseed cakes and meals. Key:* A = *meat (four main types);* B = *milk (cow, buffalo, sheep and goat);* C = *grains used as feed;* D = *oilseed cakes and meals (in protein equivalent).*

This article has been provided by the FAO Commodities and Trade Division, FAO, Via delle Terme di Caracalla, 00100 Rome, Italy.

[1] *FAO Agricultural Commodity Projections, 1975-1985.* Rome, 1979.

is important would show the greatest increase. Consequently, the feed use of grains is projected to rise from 483 million tons in 1972-74 to more than 628 million tons in 1985. Most of the increase in grain-feed use will be in developed countries where the 1985 demand is expected to be over 515 million tons compared with only a little more than 113 million tons in the developing countries.

These demand figures reflect the substantial differences between livestock productivity in the developed and developing countries. Developed countries, with less than 40 percent of the world animal units, produce about two thirds of the global output of meat and eggs and almost 80 percent of the milk. Although some of the differences in productivity may be explained by differences in resource endowment, most are the result of differences in breeding, management and feeding of livestock. Indeed, the substantial increase in the output of livestock products in developed countries during the post-war period has been closely linked with improvements in animal nutrition. However, when scientific animal breeding programmes and modern feeding methods have been applied in developing countries, the results have been comparable to those in developed countries.

TABLE 1. **Estimated feed use of grains**

Thousand tons

Regions and countries	1962-64 (Average)	1972-74 (Average)	1973	1974	1975	1976	1977 (Preliminary)	Projected demand 1985 (Basic)	Percentage annual growth rates	
									1962-64 to 1972-74	1972-74 to 1985 (Basic)
WORLD	309 497	483 338	496 646	473 445	469 486	495 598	507 513	628 421	4.6	2.2
DEVELOPING	47 133	70 988	68 861	73 883	76 469	80 487	83 906	113 236	4.2	3.9
Africa	1 201	2 161	2 105	2 383	2 728	3 034	2 794	4 581	6.0	6.5
Latin America	12 905	24 142	23 594	27 338	27 419	28 285	30 806	40 984	6.5	4.5
Brazil	6 385	8 973	8 727	10 415	10 277	12 101	12 869	16 965	3.5	5.5
Near East	7 439	9 454	8 380	8 935	10 323	12 206	12 300	15 440	2.4	4.2
Turkey	5 159	5 299	5 055	5 175	5 712	7 077	7 186	7 822	0.3	3.3
Far East	1 398	3 107	3 103	3 076	3 428	3 934	4 365	7 469	8.3	7.6
Asian centrally planned economies	24 184	32 119	31 673	32 146	32 564	33 021	33 635	44 754	2.9	2.8
China	23 261	31 032	30 208	30 757	31 273	31 579	32 139	43 456	2.9	2.9
Other developing	2	5	6	5	7	7	6	8	9.6	4.0
DEVELOPED	262 364	412 350	427 785	399 562	393 017	415 111	423 607	515 185	4.6	1.9
North America	118 671	146 681	159 766	123 054	134 474	130 310	139 532	165 463	2.1	1.0
Canada	12 047	16 305	16 649	15 897	17 122	15 427	17 082	18 944	3.1	1.3
USA	106 624	130 376	143 117	107 157	117 352	114 883	122 450	146 519	2.0	1.0
Western Europe	72 428	102 892	106 002	104 792	102 947	100 320	103 678	118 651	3.6	1.2
EEC	54 454	70 812	71 472	69 572	67 613	66 885	70 881	79 347	2.7	1.0
Spain	4 614	10 292	9 932	12 222	12 777	10 308	10 352	12 938	8.4	1.9
Yugoslavia	5 417	7 766	7 600	7 850	7 721	8 012	7 909	10 267	3.7	2.4
Eastern Europe and USSR	62 608	143 767	142 360	151 478	136 968	165 357	160 022	203 499	8.7	2.9
Poland	8 193	15 992	15 870	18 118	15 555	17 692	16 954	19 840	6.9	1.8
USSR	35 900	93 672	92 897	98 031	83 355	109 633	104 447	142 309	10.1	3.6
Oceania	2 222	3 481	3 623	3 401	3 777	2 974	2 735	3 883	4.6	0.9
Other developed	6 435	15 529	16 034	16 837	16 016	18 095	18 560	23 689	9.2	3.6
Japan	4 592	11 932	12 454	12 988	12 099	13 489	14 012	18 682	10.0	3.8

Source: FAO estimates.

Total feed resources and concentrate feeds. The statistical information on total feed resources is scanty. In particular, information about the feed contributions of grassland and rangelands, of forage and fodder crops, and of by-products and household waste used on farms, is limited to only a relatively few developed countries.

Feed balance sheets with estimates of total feed resources have been published for a number of years only by the United States, EEC and USSR. These show significant variations in the importance of the different kinds of feed in the various countries, reflecting different agricultural, livestock and feed-resource patterns. As might be expected, a higher proportion of grains is used for feeding in the United States than in Europe. In the European Community, where grain prices are set at relatively high levels by the Common Agricultural Policy, grassland and fodder are more intensively utilized than in the United States and cereal substitutes, such as cassava, pulps and processing by-products, are steadily increasing their

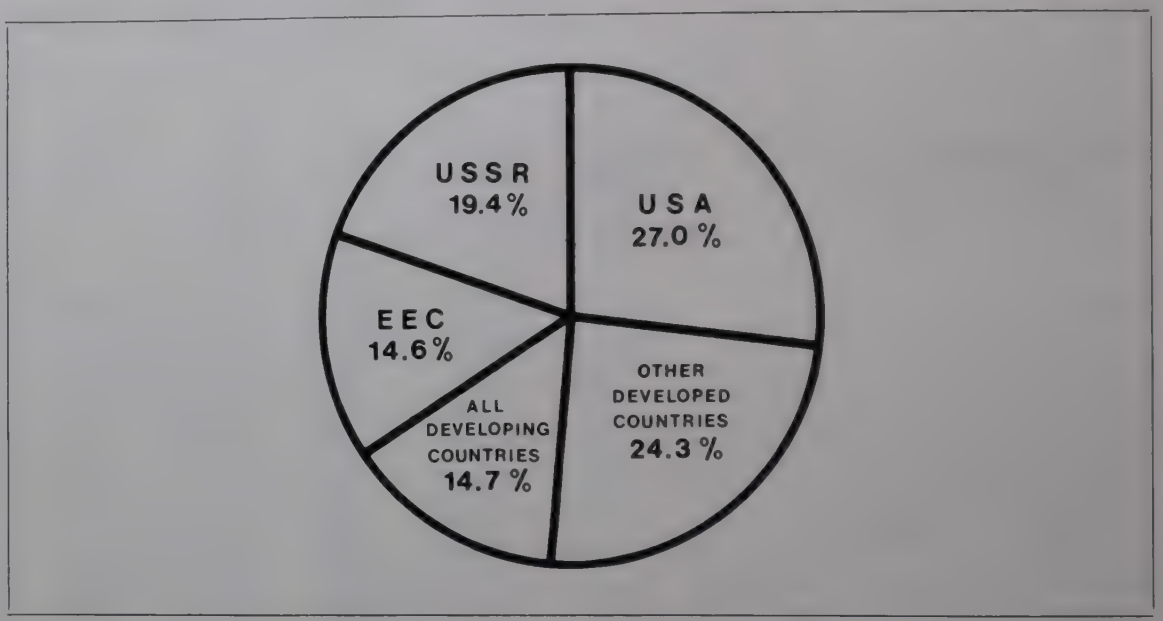
share of the total feed used. In the USSR, existing policies favour the greater use of treated fodder, such as silage, grass pellets, treated straw and stalks. Overall the proportion of all concentrates in the total feed resources used varies (in terms of feed units) from a little under 45 percent in EEC and the United States to 31 percent in the USSR (Table 2).

FAO estimates that worldwide grains provide over three quarters of the metabolizable energy [2] and about half of the crude protein absorbed by livestock from the main concentrate feeds (Table 3). By-products of cereal-milling and agricultural processing account for about 12 percent of the energy and 14 percent of the protein. Oilcakes and meals, while providing 10 percent of the energy, provide nearly one third of the protein [3].

About 85 percent of the energy and protein from grains is used in developed countries but a feature that distinguishes feeding patterns in most developing regions from those in developed countries is the high proportion of milling by-products (including rice bran and pollard) compared with that of grains in the livestock rations. This pattern reflects the local availability of feedstuffs and may be expected to change as the by-product resources become fully utilized.

The feed use of grains. The use of grains as animal feed increased rapidly in the 1950s and the 1960s under the impact of the rising demand for livestock products, particularly in developed countries. The rate of growth was checked by scarcities and

Figure 2. *The pattern of grain use in animal feeding, 1972-74 (in terms of metabolizable energy).* (SOURCE: FAO DOCUMENT CCP: ME 79/6)



[2] Metabolizable energy (ME) is the gross energy of feed minus energy lost in products of digestion.

[3] Statistics on other concentrate feeds — including milk products, pulses, sugar molasses, potatoes, beet and citrus pulp, maize gluten and tallow — are available for certain countries, but the data are too fragmentary to be included in regional aggregates.

TABLE 2. **Pattern of total feed resources** [1]

Resource	Germany, Fed. Rep.		Netherlands		United Kingdom		EEC		United States		USSR	
	1963/64-1965/66 '000 tons	1973/74-1975/76 grain units [2]	1965/66 million feed units [3]	1975/76 million feed units [3]	1970/71 million feed units [4]	1975/76 million feed units [4]	1970/71 million feed units [4]	1975/76 million feed units [4]	1962-64 '000 tons	1972-74 feed units [5]	1970 '000 tons	1972-74 feed units
Cereals	11 084 (25.6)	16 589 (31.6)	3 667 (26.0)	3 156 (17.1)	13 092 (28.3)	12 041 (25.9)	67 266 (25.3)	68 636 (25.1)	118 348 (31.4)	148 090 (33.0)	89 100 (27.1)	93 972 (25.7)
Cereal substitutes	2 167 (5.0)	2 546 (4.9)	1 903 (13.5)	4 479 (24.2)	3 203 (6.9)	2 532 (5.5)	19 669 (7.4)	20 403 (7.4)				
Oilcakes	2 775 (6.4)	4 462 (8.5)	886 (6.3)	2 097 (11.4)	1 270 (2.7)	1 567 (3.4)	13 504 (5.1)	17 438 (6.4)				
Other high nutrient density feeds	586 (1.4)	434 (0.8)	436 (3.1)	1 234 (6.7)	631 (1.4)	767 (1.6)	3 894 (1.5)	3 932 (1.4)	41 880 (11.1)	45 523 (10.1)	14 100 (4.3)	20 328 (5.5)
Milk products	2 391 (5.5)	1 412 (2.7)	275 (2.0)	492 (2.7)	163 (0.4)	679 (1.5)	5 713 (2.2)	6 234 (2.3)				
Meadows and grasslands	18 188 (42.0)	21 387 (40.8)	6 182 (43.9)	6 187 (33.5)	26 506 (57.2)	27 044 (58.2)	127 627 (48.0)	126 096 (46.1)	145 927 (38.8)	169 569 (37.8)	225 000 (68.6)	251 000 (68.8)
Other arable land resources	6 096 (14.1)	5 642 (10.7)	735 (5.2)	807 (4.4)	1 437 (3.1)	1 828 (3.9)	28 002 (10.5)	30 997 (11.3)	70 519 (18.7)	85 551 (19.1)		
Total	43 287 (100.0)	52 472 (100.0)	14 084 (100.0)	18 452 (100.0)	46 302 (100.0)	46 458 (100.0)	265 675 (100.0)	273 736 (100.0)	376 674 (100.0)	448 733 (100.0)	328 200 (100.0)	365 000 (100.0)

Sources: Germany Fed Rep Statistisches Jahrbuch über Ernährung, Landwirtschaft und Forsten 1971, 1977; Netherlands: 1965/66 Survey of Animal Feed (EEC), 1975-76 Eurostat Feed Balance Sheets; United States: Livestock Feed Relationships, National and State, Supplement for 1974 to Statistical Bulletin No 530, ERS, USDA; United Kingdom: EEC: Eurostat Feed Balance Sheets; USSR: Central Statistical Office.

NOTE: Bracketed figures are percentages of total feed.

[1] Does not include pet feeds or feedstuffs of industrial origin. — [2] Based on starch content. — [3] Products converted into starch units and then converted into feed units. — [4] Feed unit equivalent to net energy value of 1 kg of barley. — [5] In maize equivalent.

TABLE 3. **Pattern of world consumption of main concentrate feedstuffs, 1972-74**

Region	Metabolizable energy (Million megacalories)				Crude protein (Million metric tons)			
	Grains and rice [1]	Milling by-products	Oilcakes and meals	Total	Grains and rice [1]	Milling by-products	Oilcakes and meals	Total
WORLD	1 331	210	170	1 711	52	13	29	94
Developing	199	110	43	352	8	6	7	21
Africa	6	6	2	14	—	—	—	1
Latin America	67	10	8	85	2	0.6	1	4
Near East	26	8	3	37	1	0.5	0.5	2
Far East	12	36	12	60	—	2	2	4
Asian centrally planned economies	88	50	18	156	4	3	3	10
Developed	1 131	100	127	1 358	44	6	22	72
North America	405	15	40	460	14	1	7	22
Western Europa	280	31	50	361	11	2	8	21
Oceania	9	1	2	12	—	—	—	1
Eastern Europe and USSR	392	45	25	462	17	3	4	24
Other developed countries	43	8	10	63	2	—	2	4

Source: FAO Commodities and Trade Division.

[1] In developed countries outside Japan, the role of rice as animal feed is insignificant, while in developing countries the quantity of rice used as feed is small but slowly growing. In the table, a dash (—) signifies that the amount is insignificant.

the high price of grains during the world food crisis of 1973/74, and by a slackening in the demand for animal products in developed countries as a result of the economic slowdown of 1974. However, following better harvests after 1975, the feed use of grains has tended to rise again, though slower economic growth in industrialized countries may keep future rates of increase lower than they were in the past.

Developed countries account for over 80 percent of the world's grain-feed use, the United States alone accounting for between 25 and 30 percent (Figure 2). The major expansion in grain feeding in the United States occurred before 1960. In the late 1960s there was another sharp increase for a short period associated with the growth of beef feedlot production based on intensive grain feeding. This rise was checked in 1973 when a steep increase in grain prices caused a reappraisal of beef production methods. Between 1973 and 1974 the amount of grain used for feed in the United States decreased by 36 million tons (25 percent of the country's total grain use), reflecting a return to greater grassland-based beef production. Prospects for feedlot production again became more favourable between 1977 and 1978 when grain prices were relatively low and beef prices rose.

In Western Europe the expansion in the use of grains for feed was substantial in the 1960s but high grain prices in EEC, maintained under the Common Agricultural Policy, have encouraged the search for grain substitutes, such as cassava, copra meal and citrus and beet pulp, as well as the greater use of soybean meal. This substitution process has gone furthest in the Netherlands and in northern Germany (FR) where excellent shipping facilities and easy access to world markets facilitate the replacement of feedgrains by cheaper feed components.

Grain feeding in the USSR nearly trebled in the 1960s in line with the expansion in domestic grain production. Because of the shortage of protein feeds in the country, more reliance was placed on grains as a source of protein. In the early 1970s with demand for grains increasing faster than supplies, substantial quantities of feedgrains were imported — in addition to the imports of wheat for food — in order to maintain the expansion of livestock production.

Japanese use of grains for feed represents only about 3 percent of the world total but the growth rate in Japan was among the highest of the developed countries in the 1960s and 1970s (when meat, egg and milk production expanded strongly from a low base). The livestock sector in Japan is heavily dependent on imported concentrates, which consist mainly of coarse grains and oilcakes and meals.

In developing countries (as was pointed out by several delegates at the eighth session of the Intergovernmental Group on Meat [4]), there is competition between human population and livestock in the use of agricultural land so that the use of grains as animal feed when human requirements are not fully met is difficult to justify. Consequently, only small amounts of grains have been used for animal feeding and, in most of these countries there was, until recently, no clear distinction between food- and feedgrains, both being consumed as food when necessity demanded. Grain feeding as a regular practice is a new development in many of these countries, and, even after a fairly

[4] FAO. 1979. Rome. FAO Document CCP: 79/6.

rapid growth (over 4 percent a year since the early 1960s), the developing countries' use of grain for feed still accounts for less than 20 percent of global grain-feed utilization. In these countries concentrate feeding tends to be practised mainly in the commercial dairy, pig and poultry sectors near urban areas.

FAO estimates that in developing countries a high proportion of the grain used as feed is incorporated in compound feeds specially prepared for poultry, pig and dairy cattle feeding. During the past five years an annual growth in compound feed consumption of over 8 percent has been reported from a number of developing countries, such as Brazil, Egypt, Iran, Republic of Korea, Mexico, Nigeria, Thailand, Turkey and Venezuela.

China produces over 70 percent of the pig meat and between 40 and 50 percent of the poultry meat and eggs produced by the developing countries. are fed to livestock, mainly pigs and poultry.

The Far East, excluding China, accounts for less than 5 percent of the grain used as feed by developing countries, though it has shown the highest growth rate of all regions since the early 1960s. In recent years the rate of growth has accelerated in a number of countries of this region largely because of the rapid expansion of the poultry sectors, particularly in Malaysia, the Republic of Korea and Thailand.

In the Near East, too, the output of poultry meat, eggs and milk has grown significantly since 1972-74, and grain-feed usage is increasing rapidly.

In Africa, except near urban centres, the use of grain as feed is on a small scale although consumption is rapidly growing in Egypt, Morocco, Nigeria and Tunisia.

After China, Latin America is the main feedgrain consuming region, accounting for an estimated 35 percent

the different types of animals makes it difficult to identify trends in grain feeding by end use, the available data indicate that the amount of grain used to produce meat, milk and eggs has considerably increased in all regions since the early 1960s due partly to more intensive feeding and partly to changes in the pattern of production of the various types of meat (Table 4). Features of this pattern since the early 1960s have been the rapid expansion in the output of poultry meat (heavily dependent on feedgrains) and the slow growth in the production of sheep meat (almost entirely dependent on grassland). The output of pig meat (also largely based on grains) has increased substantially in those developing countries where its production is not restricted for religious reasons.

The use of grains as feed has increased with the wider adoption of modern forms of animal production, which tend to be more grain-absorptive

TABLE 4. **Trends in the output of livestock products**

Product	Developing countries				Developed countries			
	Production growth rates (Percentage per annum)		Percentage of all meat		Production growth rates (Percentage per annum)		Percentage of all meat	
	1962-64 to 1972-74	1972-74 to 1975-77	1962-64	1972-74	1962-64 to 1972-74	1972-74 to 1975-77	1962-64	1972-74
Beef and veal	1.9	3.4	40	36	3.3	4.9	39	41
Pig meat	2.8	2.3	38	37	2.7	—	39	34
Poultry meat	6.8	5.0	11	18	6.3	3.6	15	21
Sheep meat	1.4	2.2	11	9	0.1	—1.2	7	4
All meat	2.8	3.2	100	100	3.4	1.0	100	100
Milk	2.4	3.4			1.5	1.0		
Eggs	3.9	3.3			2.7	1.4		

Source: FAO Agricultural Commodity Projections 1975-1985.

In this case the traditional pig feeds — including household wastes, food processing by-products and forage crops — are supplemented by considerable quantities of grains. In the absence of official statistics, estimates of Chinese feed consumption are liable to a substantial degree of error, but it is tentatively estimated that in China over 30 million tons of grains of the total for developing countries. Feed use is high relative to total grain consumption (33 percent) and has been growing at an average rate of over 6 percent a year since the early 1960s.

Factors affecting the use of grains as feed. Though the paucity of information on feed consumption by

than older systems. Selective breeding, better livestock management, intensive feeding methods, the shortening of the production cycles, particularly in the case of poultry, pigs and young cattle, are all factors that have led to increased dependence on grains for feeding. Generally speaking, intensive livestock feeding tends to lead, initially, to greater demand for

grains; in the longer term, however, as compound feed technology advances, new types of cheaper feed components (such as cassava and processing by-products) often replace part of the grains.

An important factor in the use of grains as feed is the relationship between the price of livestock products and grains, i.e., the livestock/grain-price ratio [5]. Since the 1950s the prices of most livestock products have risen more rapidly than the cost of the grains required to produce them, resulting in a rising trend in the livestock/grain-price ratio, which, in turn, has contributed to the increased use of feedgrains. Consumer demand has been particularly strong for beef; in the case of pig and poultry the incentives of high product/feed-price ratios were augmented by improvements in feed conversion ratios.

Feedgrain use is also affected by the relative prices of grains and other feeds, especially of grain substitutes and oilcakes and meals. Although, to some extent, the latter feeds are complementary to grain, if grain prices rise beyond a certain point, substitution by cheaper energy-providing feeds, such as cassava and various pulps, becomes profitable. In addition, the protein content of grains may be replaced by additional quantities of oilcakes and meals.

The development of compound-feed manufacture is a significant factor in the use of grains for feeding, since it provides flexibility in the use of grains depending on availability and price. In countries where the compound feed industry produces mainly complementary feed mixes for addition to grain, as is the case in Canada, the proportion of grain used as a component of compound feed is low. However, where the industry produces complete feeds, the share of grains in compound feeds has varied from 30 percent in the Netherlands to 48 percent in France, and over 50 percent in Italy and the United Kingdom. In Japan, which utilizes only a narrow range of ingredients in its mixed feeds, the share of grains is two thirds. In most developing countries the proportion of grains in compound feeds is even higher, though in a number of places increasing attention is being given to the possibility of using more locally available feed ingredients to supplement imported grains to the greatest extent possible.

Outlook and development issues. FAO projections of supply, demand and trade of grains for animal feed suggest that the growth in the demand for feedgrains over the next decade will be smaller than it was in the previous one [6] (Table 1). The slowing down is related to the expected lower growth rate in the output of animal products in developed countries where consumption of meat and milk is already at a high level and where both population and income growth are expected to be small. In developing countries, however, the growth of both meat and milk production is expected to accelerate, and the increased livestock production would result in strong demand for feedstuffs. The demand for feedgrains in developing countries is thus projected to grow by 3.9 percent per year between 1972-74 and 1985, compared with only 1.9 percent per year in developed countries. Putting this growth in perspective, however, the actual volume-increase projected in developing countries for 1985 (30 million tons) would still be only about one third of the 90 million tons' increase projected for developed countries.

On the production side, developed regions have the capacity to expand their output of grains or to import their grain needs and will probably keep the growth of production more or less in line with demand growth. However, because of constraints such as shortage of land, capital, modern technology and low policy priority for grains as animal feed, the production of coarse grains in developing countries is expected to grow at a rate of only 2.1 to 2.4 percent a year over the period to 1985, compared with total meat production of 3.2 percent and milk production of 3.1 percent. The livestock industries of many of these latter countries could thus become increasingly dependent on imported feedstuffs and in many the lack of animal feeds could jeopardize national livestock development plans dependent on imported feedstuffs. This was recognized during the eighth session of the Intergovernmental Group on Meat (Rome, May 1979), when many delegates expressed concern regarding their increasing dependence on imported feeds, especially maize and soybean meal.

It should be stressed that the projections for livestock products and feed use of grains to 1985 assume, by and large, continuation of current policies in the feed/livestock sector. A change in policies would have considerable repercussions on future feed use of grains. For example, if policies in the developing countries were to give more emphasis to rural, smallholder production of livestock, they could lead to greater use of locally available feed supplies, and consequently to lower imports of grains and other feeds from abroad than projected.

Possible policy changes could also reduce the demand for feedgrains in the developed regions. For instance, in Eastern Europe and the USSR, the marked rise in demand for animal products in the past has been partly due to a policy of stable consumer prices, while retail prices have in many cases not been changed for more than a decade; prices to producers have been raised substantially, requiring growing subsidies to livestock industries. If, in the future, governments decide to limit these subsidies, increase in demand for the relatively high price-elastic animal products and consequently increase in their output would probably be slower than projected. In turn, this could slow down the growth in the projected demand for feedstuffs, and particularly feedgrains, in these countries.

---

[5] These ratios indicate the number of kilograms of grains one kilogram of slaughter cattle, pig or poultry will buy at given prices.

[6] The projections of demand for feed were linked to projections of production of livestock products, using input/output coefficients, taking account of the composition of livestock rations and of prospective changes in the efficiency of feed use and in the efficiency of feedstuffs manufacturing industries.

Similarly, in developed market economies, the projected slowdown in the expansion of feed use of grains could be even greater if livestock production policies were changed in order to adjust output of commodities produced in surplus, or as a result of lowering protection of national livestock markets, or for broader socio-economic and ecological considerations. While an adjustment of surplus production, mainly in Western Europe, would especially affect the demand for protein feeds, it would to some extent also reduce feedgrain requirements. Lowering the degree of protection of the high-priced markets for animal products in the Northern Hemisphere should lead to an increase in the demand, notably for meat, over and above the projected levels. This would, however, probably benefit mostly beef while the demand for and production of pig and poultry meat in this region might decline, thereby reducing demand for feedgrains. A reorientation of livestock production policies for overall socio-economic and ecological reasons would also probably benefit less-intensive forms of cattle, sheep and possibly game production or horse-raising rather than the heavily grain-based pig and poultry farming.

The projections of livestock products and feed use of grains to 1985 underline several important issues that are vital for the development of the feed/livestock sector, especially in the developing countries. The first and foremost is the need to remove the existing constraints that have impeded the development of the sector in the past. These constraints — notably shortage of feed resources, lack of adequate technology and unremunerative prices — vary in severity between countries. However, their removal or alleviation would call for the adoption of policies that are appropriate to the situation in each country. Some of the issues that will need to be considered in the formulation of strategies for the feed/livestock sector are discussed below.

A sufficient supply of feedstuffs, including forage crops, grassland production, feedgrains and other concentrate feeds, is an essential prerequisite for a rapidly growing livestock sector. Governments should devote serious attention to policies and programmes for increasing the supply of feedstuffs, especially of feedgrains. Pricing policies are important but they need to be carefully designed so that incentives necessary to stimulate additional production of feedstuffs do not price them out of the economic reach of livestock producers. Generally, price policies would need to be complemented by other forms of encouragment and assistance in the production of feedstuffs, including technical assistance, improved extension services, and effective credit arrangements to help producers acquire the necessary inputs, notably improved seeds and fertilizers.

The projections suggest a rapid expansion of consumption and production of poultry and pig meat and consequently a fast increase in grain feeding in developing countries. While progress in the rationalization of meat production from ruminants is expected to be slow, modern technology in pig and poultry production can be more easily transferred from developed to developing countries. However, it is necessary to ensure that transfer of technology goes beyond the establishment of large-scale, sophisticated enterprises in peri-urban areas, which often are not based on locally available feedstuffs and have little impact on agricultural development in the countryside. It is therefore desirable to review and, where necessary, adapt livestock development policies so as to achieve a closer integration of the livestock sector with overall agricultural development.

Recently, national governments and international agencies have in fact given more emphasis to programmes designed to develop rural, smallholder production of meat, milk and eggs. While this is often a laborious and slow process, it is likely to yield benefits in the longer run insofar as it improves rural employment and nutrition, helps to intensify and diversify agriculture and to increase self-reliance. The gradual mechanization of farming, which releases labour and feed, would also call for such an intensification of agriculture. Technical assistance within such programmes would have to be accompanied by policies assuring reasonable returns to rural producers.

Compound-feed manufacture can play an important part in helping developing countries to obtain the best results from improved genetic stocks, particularly in pig and poultry development. However, the compound-feed industry tends to raise concentrate, and particularly grain, requirements, which can in many cases lead to increased imports. It is therefore necessary to explore the possibility of developing a compound-feed technology that would absorb more locally available feedstuffs and so supplement the imports of grains and oilcakes to the maximum extent possible.

Areas where the international community could contribute to livestock-sector development in developing countries include technical assistance and the transfer of technology. Increased technical assistance, which should include expertise in animal husbandry and feeding and in feed formulation in compound-feed manufacture, would help developing countries to take greater advantage of modern technology in the development of the livestock sector.

There is limited information on government policies and programmes for feedstuffs development in developing countries. Policy formation is often inhibited by the poor information available regarding feed resources, in particular the present and potential contribution of grasslands, forage crops and agro-industrial wastes, and by inadequate knowledge of feed/livestock input/output relationships under different livestock systems. Sound basic data are clearly important as a foundation for policy-making, and there is thus a need to collect and analyse more information on current and potential feed resources in developing countries, as well as on the utilization of these resources under different livestock farming systems. Such analysis should also take account of social factors that affect farming in these countries and examine changes that may be necessary or desirable for the achievement of agricultural and food policy objectives. ■

SHORT COMUNICATION

The present position of bluetongue virus in Australia

FAO has received a number of inquiries from developing countries anxious to obtain the latest information regarding the position in Australia of bluetongue virus. The countries are either contemplating the purchase of livestock from that country or wish to benefit from Australia's experience. This communication describes the position in Australia and the precautions importing countries should take.

The position in Australia. As is well known, bluetongue is an infectious but non-contagious viral disease of sheep, which may also affect cattle. It is transmitted in nature only by the bites of insects of the genus *Culicoides* and artificially by the inoculation of infected blood. The first isolation of the bluetongue virus in Australia was from *Culicoides* insects collected in the Northern Territory of the country in March 1975 in the course of a research project.

The virus was identified as a bluetongue virus by the Yale arbovirus reference laboratory in October 1977. This identification was later confirmed by the Veterinary Research Institute, Ondersterport, which found the virus to be sufficiently antigenically different from other bluetongue virus strains as to justify it being designated a new serotype strain (BT20).

When the discovery of bluetongue virus was confirmed, all veterinarians and stock inspectors in Australia were alerted to the possibility of clinical bluetongue disease and were made familiar with the usual symptoms of the disease. In spite of intensive surveillance over the past eighteen months *there has been no evidence of any clinical disease associated with bluetongue infection of any livestock species in Australia*.

Experimentally the new strain (BT20) appears to be moderately pathogenic for sheep, some of which in the experiments developed a febrile reaction, a viraemia and a number of clinical signs and lesions. But there were no deaths in these experimentally infected sheep.

In the case of experimentally infected adult non-pregnant cattle, these developed a febrile reaction and viraemia but no clinical signs.

Although the BT20 strain of the virus has not yet been isolated from a vertebrate host in Australia there is serological evidence of infection from this strain in cattle and buffaloes in the field, but not in sheep.

Serological surveys have shown that BT20 infection has occurred only in the far north of Western Australia, the Northern Territory and Queensland, antibodies to the virus having been detected in cattle, buffaloes and one goat in these areas. The movement of serologically positive animals from the northern infected area to other regions before controls were instituted was not, however, responsible for any known secondary foci of infection.

The serological surveys (200 000 animals tested from 800 locations) have also shown that there has been minimal virus activity over the last 20 months and that the geographical distribution of BT20 has contracted very considerably during this period. There is evidence of recent virus transmission

only on three properties in the far north of the continent.

Positive reactions to group-specific bluetongue serological tests have been found in some serum samples collected in other parts of Australia. These, however, were negative to serum neutralization tests against BT20. The significance of these reactions is as yet unknown. There is some evidence that they may be due, at least in part, to cross-reactions with other non-pathogenic arboviruses (a particular group of arthropod-borne viruses).

In regard to *Culicoides* vector of the virus, six potential species of the insect have thus far been identified as being capable of multiplying BT20 virus.

When the presence of bluetongue virus in Australia was confirmed, severe restrictions were placed on the movement of ruminant animals out of known infected areas in the attempts made by the authorities to delay the spread of the virus. (These attempts included provisions for the designation of "restricted", "control" and "free" areas). These controls have now been modified. Restrictions have been retained only on the movement of animals from properties with serological evidence of active infection.

Precautions to be taken by importing countries. From the point of view of those countries wishing to import livestock or livestock products from Australia, it must be appreciated that bluetongue cannot be transmitted by direct or indirect contact. The importation of livestock products from Australia would, therefore, be perfectly safe so far as bluetongue disease is concerned.

In the case of livestock from Australia, FAO's advice to intending importers is that ruminants and their semen from areas other than the limited area in which restrictions still apply could be safely imported provided the animals were individually tested and certified free of bluetongue virus prior to export.

FAO further advises that in any procurement agreement between Australia and an importing country such an agreement should provide for the reservation by the importing country of the right to apply animal health conditions, and even the suspension of imports when justified on animal health grounds.

The animal health position in any country can of course unpredictably deteriorate at any time so that, in any case, FAO would always recommend as a routine practice the inclusion of such animal health reservation clauses in all animal procurement agreements.

Distribution of properties with herds positive to bluetongue up to 31 December 1977. The serum neutralization test was used on cattle of all ages.

international information system
for the
agricultural sciences and technology

AGRIS is a cooperative system for collecting and making known current information on the world's agricultural literature, in which at present more than 100 national and multinational centres take part. The world production of literature of agricultural interest is vast, being proportionate to the importance of food production in the international economy. By the end of 1978 the AGRIS data base had accumulated more than 355 000 references and is now increasing at a monthly rate of some 10 000 references of which about one-sixth are of non-conventional literature. These are published monthly in the form of the printed volume *Agrindex* and on magnetic tape. Cumulative author and subject indexes to the first three volumes of *Agrindex* were published in 1978 and in future will be published every two years.

FAO received a mandate from its 17th Conference to begin the operation of AGRIS in January 1975 and is responsible for the coordination of the system and the central processing of the data. Each country agreeing to participate in AGRIS is responsible for contributing the information produced within its territory; in return it benefits from the collected and combined total information contributed by all the participating countries. FAO's contacts with participating countries are established through nationally appointed AGRIS liaison offices.

Agrindex provides comprehensive coverage in 85 subject categories grouped into 17 major areas of agriculture, nutrition, forestry, fisheries and rural development. *Almost every aspect of animal production and health is covered by AGRIS, under the following heads: animal production (including poultry farming), animal science, animal breeding, animal ecology, animal nutrition, feed processing, feed microbiology and toxicology, feed composition, animal structure, animal physiology and biochemistry, animal toxonomy and geography, veterinary science and hygiene, pests of animals, animal diseases and miscellaneous disorders of animals.*

Specialists, wherever they may be, having access to a library or to other subscribers to *Agrindex* are now able to keep abreast of the new literature by regularly scanning *Agrindex* to find pertinent references in which they are interested. This can be done under the specific subject, personal author, corporate entry, report number and under commodities. With these indexes users of *Agrindex* can quickly select literature of interest to them.

Having identified references of interest users can proceed to locate the corresponding documents in the library they are using or apply to any one of the "Aglinet" libraries listed in *Agrindex* or, in the case of literature not available commercially, to the contributors of the reference or to one of the AGRIS input centres as listed in *Agrindex.*

Those who have access to a computer can make use of the AGRIS magnetic tape for searching all the information contributed to AGRIS for the desired literature.

AGRIS is the first attempt to internationalize agricultural information. The methods it is exploring will have considerable influence on the future of international agricultural documentation. For any additional information regarding AGRIS and its products write to:

AGRIS Coordinating Centre
FAO
Via delle Terme di Caracalla
00100 Rome, Italy

NEWS

International training courses on pig and poultry husbandry

The International Training Centre at Barneveld College, The Netherlands, will conduct the 10th international course on poultry husbandry and the 10th international course on pig husbandry from 27 August 1980 to 27 February 1981.

The courses are primarily meant for candidates from developing countries, who preferably perform teaching and advisory functions in pig and/or poultry husbandry or closely related fields.

The courses are intended to refresh the knowledge of the participants and to provide additional information on important aspects of poultry or pig husbandry, including economics, genetics, breeding, hygiene and disease prevention, nutrition, housing and management. Most attention will be paid to those aspects which may lead to higher egg and meat production in the short term.

The courses will be conducted in English.

Coverage includes theoretical studies, practice classes, practical instructions and demonstrations, a compulsory traineeship and applied management period in the College farms, laboratory work, writing of reports and excursions.

Details regarding admission requirements, fees, accommodation, and the syllabuses for the two courses can be obtained from The Director (I.H. Rietberg), Barneveld College, PO Box 64, 3770 AB Barneveld, The Netherlands.

Eighth international course on dairy cattle husbandry

The eighth course of the series of international courses on dairy cattle husbandry organized by the Dutch International Agricultural Centre will be held in the Netherlands from 11 March to 13 June 1980. Participants should have an agricultural or veterinary education up to at least BSc level as well as three years' experience in dairy cattle husbandry or a closely related subject. The course will be conducted in English.

Further information may be obtained from the Director of the International Agricultural Centre, PO Box 88, 6700 AB Wageningen, The Netherlands.

Corrigendum

World Animal Review 30, 1979. *Buffalo milk technology.* Figure 1 on page 3 should be as shown here.

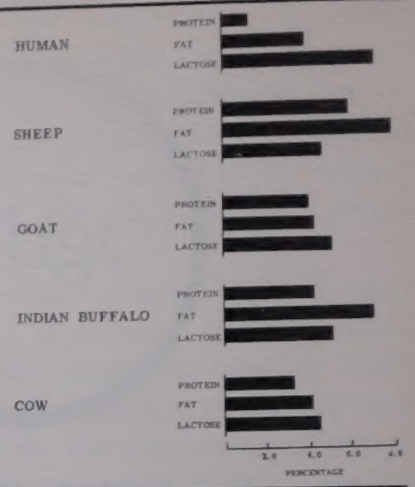


Figure 1. *Composition of milk from different sources*

COMMENT

(Continued from front cover)

represented an important step forward in promoting the use of such feedstuffs. FAO collects and disseminates the result of work such as that done on te utilization of rations based on molasses and sugar cane and other agro-industrial by-products and publishes major technical documents in this field such as *Tropical Feeds, Tropical Forage Legumes* and *Treating Straw for Animal Feeding.* In the field of feed economics the FAO statistics on grasslands and on major feed concentrates, and reports prepared for inter-governmental group meetings, such as the recent study on the utilization of grains in the livestock sector, have also been of value to developing countries in the planning of their livestock/feed policies. (See also the article on page 42 of this issue.)

FAO is anxious to encourage research and investigation into the increased utilization of new feed resources and the development of projects in individual countries, including simple pilot-scale experimentation and demonstration projects.

Countries faced with rising demands for animal products and requiring assistance in the development of their feed resources should therefore notify FAO of their needs and request assistance in this field.

A number of articles concerning the potential of poor-quality agricultural roughages and agro-industrial by-products, their treatment and use for animal feeding have appeared in previous issues of World Animal Review. These include the following (issue in **boldface,** page in *italic)*:

28 *38* JACKSON, M.G. Treating straw for animal feeding — an assessment of its techcal and economic feasibility

28 *31* RANJHAN, S.K. Use of agro-industrial by-products in feeding ruminants in India

28 *44* } PRESTON, T.R. and LENG, R.A. Sugar cane as cattle feed (in two parts)
27 *7* }

26 *13* SUNDSTØL, F., COXWORTH, E. and MOWAT, D.N. Improving the nutritive quality of straw and other low quality roughages by treatment with ammonia

25 *25* MULLER, Z.O. Feeding potential of pineapple waste for cattle

23 *25* JACKSON, M.G. Rice straw as livestock feed

22 *2* KEMPTON, T.J., NOLAN, J.V. and LENG, R.A. Principles for the use of non-protein nitrogen and by-pass proteins in diets for ruminants

21 *18* CORDIEZ, E., LAMBOT, O., BIENFAIT, J.M., PONDANT, A. and VAN EENAEME, C. Saving grain in beef production by feeding dried sugar beet pulp

20 *22* LE DIVIDICH, J., GEOFFROY, F., CANOPE, I. and CHENOST, M. Using waste bananas as animal feed

20 *31* WARD, G.M. and MUSCATO, T. Processing cattle waste for recycling as animal feed

18 *39* BELLAMY, W.D. Production of single-cell protein for animal feed from lignocellulose wastes

15 *39* DYER, I.A., RIQUELME, E., BARIBO, L. and COUCH, B.Y. Waste cellulose as an energy source for animal protein production

6 *24* GOHL, B.I. Citrus by-products for animal feed

4 *7* PIGDEN, W.J. and BENDER, F. Utilization of lignocellulose by ruminants

3 *14* TOPPS, J.H. Urea or biuret supplements to low protein grazing in Africa

1 *24* PRESTON, T.R. Fattening beef cattle on molasses in the tropics

These articles, together with the references quoted, provide a wide cover of this very important subject. In addition, two extremely relevant documents are included in the FAO Animal Production and Health Paper Series: No. 4 *New feed resources* (the proceedings and papers of a technical consultation held in 1976) and No.10 *Treating straw for animal feeding.*

Index for Nos. 29 to 32, 1979

Author

The **boldface** number refers to the issue, the *italic* to the page.

Subject

The numbers in the subject index correspond to entries in the author index.

FAO SALES AGENTS AND BOOKSELLERS

Algeria
Société nationale d'édition et de diffusion, 3, boulevard Zirout-Youcef, Algiers.

Antilles, Netherlands
St. Augustinus Boekhandel, Abraham de Veerstraat 12, Willemstad, Curaçao.

Argentina
Editorial Hemisferio Sur S.R.L., Librería Agropecuaria, Pasteur 743, Buenos Aires.

Australia
Hunter Publications, 58A Gipps Street, Collingwood, Vic. 3066; The Assistant Director, Sales and Distribution, Australian Government Publishing Service, P.O. Box 84, Canberra, A.C.T. 2600; and Australian Government Publications and Inquiry Centres in Canberra, Melbourne, Sydney, Perth, Adelaide and Hobart.

Austria
Gerold & Co., Buchhandlung und Verlag, Graben 31, 1011 Vienna.

Bangladesh
Agricultural Development Agencies in Bangladesh, P.O. Box 5045, Dacca 5.

Belgium
Service des publications de la FAO, M.J. De Lannoy, 202, avenue du Roi, 1060 Brussels. CCP 000-0808993-13.

Belize
The Belize Bookshop, P.O. Box 147, Belize.

Bolivia
Los Amigos del Libro, Perú 3712, Casilla 450, Cochabamba; Mercado 1315, La Paz; René Moreno 26, Santa Cruz; Junín esq. 6 de Octubre, Oruro.

Brazil
Livraria Mestre Jou, Rua Guaipá 518, São Paulo 10; Rua Senador Dantas 19-S205/206, Rio de Janeiro; PRODIL, Promoção e Dist. de Livros Ltda., Av. Venâncio Aires 196, Caixa Postal 4005, Porto Alegre, RS; Livraria Dom Bosco, Rua 14 de Julho 2818, Caixa Postal 962, Campo Grande, MT; A NOSSA LIVRARIA, CLS 103, Bloco C, Lojas 2/6, Brasilia, D.F.; FIMAC, Distribuidora de Livros Ltda., Rua de Bahia 478, Loja 10, Belo Horizonte, ME; METRO CUBICO, Livros e Revistas Técnicas Ltda., Praça São Sebastião, Rua 10 de Julho 613, Caixa Postal 199, Manaus, Amazonas; Distribuidora Luso Mercantil, Rua 13 de Maio 524, Caixa Postal 1124, Belém, Pará; G. Lisbóa Livros Ltda., Rua Princesa Isabel 129, Recife, PE; Livraria Cometa Distribuidora Ltda., Rua da Independencia 46, Salvador, Bahia.

Canada
Renouf Publishing Co. Ltd., 2182 Catherine St. West, Montreal, Que. H3H 1M7.

Chile
Tecnolibro S.A., Merced 753, entrepiso 15, Santiago.

China
China National Publications Import Corporation, P.O. Box 88, Peking.

Colombia
Litexsa Colombiana Ltda., Calle 55, N° 16-44, Apartado Aéreo 51340, Bogotá.

Costa Rica
Librería, Imprenta y Litografía Lehmann S.A., Apartado 10011, San José.

Cuba
Empresa de Comercio Exterior de Publicaciones, O'Reilly 407, Havana.

Cyprus
MAM, P.O. Box 1722, Nicosia.

Denmark
Ejnar Munksgaard, Norregade 6, Copenhagen S.

Dominican Rep.
Fundación Domenicana de Desarrollo, Casa de las Gárgolas, Mercedes 4, Santo Domingo.

Ecuador
Su Librería Cía. Ltda., García Moreno 1172, Apartado 2556, Quito; Calle Chimborazo 416, Guayaquil.

El Salvador
Librería Cultural Salvadoreña S.A., Calle Arce 423, Apartado Postal 2296, San Salvador.

Finland
Akateeminen Kirjakauppa, 1 Keskuskatu, Helsinki.

France
Editions A. Pedone, 13, rue Soufflot, 75005 Paris.

Germany, F.R.
Alexander Horn Internationale Buchhandlung, Spiegelgasse 9, Postfach 3340, Wiesbaden.

Ghana
Fides Enterprises, P.O. Box 1628, Accra; Ghana Publishing Corporation, P.O. Box 3632, Accra.

Greece
"Eleftheroudakis", 4 Nikis Street, Athens.

Guatemala
Distribuciones Culturales y Técnicas « Artemis », Quinta Avenida 12-11, Zona 1, Guatemala City.

Guinea-Bissau
Conselho Nacional de Cultura, Avenida da Unidade Africana, C.P. 294, Bissau.

Guyana
Guyana National Trading Corporation Ltd., 45-47 Water Street, Georgetown.

Haiti
Max Bouchereau, Librairie « A la Caravelle », B.P. 111, Port-au-Prince.

Honduras
The Bookstore, Apartado Postal 167-C, Tegucigalpa.

Hong Kong
Swindon Book Co., 13-15 Lock Road, Kowloon.

Iceland
Snaebjörn Jónsson and Co. h.f., Hafnarstraeti 9, P.O. Box 1131, Reykjavik.

India
Oxford Book and Stationery Co., Scindia House, New Delhi; 17 Park Street, Calcutta.

Indonesia
P.T. Gunung Agung, 6 Kwitang, Djakarta.

Iran
Iran Book Co. Ltd., 127 Nadershah Avenue, P.O. Box 14-1532, Tehran.

Iraq
National House for Publishing, Distributing and Advertising, Rashid Street, Baghdad.

Ireland
The Controller, Stationery Office, Dublin.

Israel
Emanuel Brown, P.O. Box 4101, 35 Allenby Road and Nachlat Benyamin Street, Tel Aviv; 9 Shlomzion Hamalka Street, Jerusalem.

Italy
Distribution and Sales Section, Food and Agriculture Organization of the United Nations, Via delle Terme di Caracalla, 00100 Rome; Libreria Scientifica Dott. L. De Biasio "Aeiou", Via Meravigli 16, 20123 Milan; Libreria Commissionaria Sansoni "Licosa", Via Lamarmora 45, C.P. 552, 50121 Florence.

Jamaica
Teacher Book Centre Ltd., 95 Church Street, Kingston.

Japan
Maruzen Company Ltd., P.O. Box 5050, Tokyo Central 100-31.

Kenya
Text Book Centre Ltd., P.O. Box 47540, Nairobi.

Korea, Rep. of
The Eul-Yoo Publishing Co. Ltd., 5 2-Ka, Chong-ro, Seoul.

Kuwait
Saeed & Samir Bookstore Co. Ltd., P.O. Box 5445, Kuwait.

Luxembourg
Service des publications de la FAO, M.J. De Lannoy, 202, avenue du Roi, 1060 Brussels (Belgium).

Mauritius
Nalanda Company Limited, 30 Bourbon Street, Port Louis.

Mexico
Dilitsa S.A., Puebla 182-D, Apartado 24-448, Mexico City 7, D.F.

Morocco
Librairie « Aux Belles Images », 281, avenue Mohammed V, Rabat.

Netherlands
N.V. Martinus Nijhoff, Lange Voorhout 9, The Hague.

New Zealand
Government Printing Office: Government Bookshops at Rutland Street, P.O. Box 5344, Auckland; Alma Street, P.O. Box 857, Hamilton; Mulgrave Street, Private Bag, Wellington; 130 Oxford Terrace, P.O. Box 1721, Christchurch; Princes Street, P.O. Box 1104, Dunedin.

Nicaragua
Librería Interamericana Nicaragüense S.A., Apartado 2206, Managua.

Nigeria
University Bookshop (Nigeria) Ltd., University of Ibadan, Ibadan.

Norway
Johan Grundt Tanum Bokhandel, Karl Johansgt. GT 41-43, Oslo 1.

Pakistan
Mirza Book Agency, 65 The Mall, Lahore 3.

Panama
Distribuidora Lewis S.A., Edificio Dorasol, Calle 25 y Avenida Balboa, Apartado 1634, Panama 1.

Paraguay
Agencia de Librerías Nizza S.A., Paraguarí 144, Asunción.

Peru
Librería Distribuidora Santa Rosa, Jirón Apurímac 375, Casilla 4937, Lima.

Philippines
The Modern Book Company, 928 Rizal Avenue, Manila.

Poland
Ars Polona-Ruch, Krakowskie Przedmiescie 7, Warsaw.

Portugal
Livraria Bertrand, S.A.R.L., Apartado 37, Amadora; Livraria Portugal, Dias y Andrade Ltda., Apartado 2681, Rua do Carmo 70-74, Lisbon-2; Edições ITAU, Avda. República 46A c/v-E, Lisbon-1.

Romania
Ilexim, Calea Grivitei N° 64-66, B.P. 2001, Bucarest.

Saudi Arabia
University Bookshop, Airport Road, P.O. Box 394, Riyadh.

Senegal
Librairie Africa, 58, avenue Georges Pompidou, B.P. 1240, Dakar.

Somalia
"Samater's", P.O. Box 936, Mogadishu.

Spain
Mundi Prensa Libros S.A., Castelló 37, Madrid-1; Librería Agrícola, Fernando VI 2, Madrid-4.

Sri Lanka
M.D. Gunasena and Co. Ltd., 217 Norris Road, Colombo 11.

Switzerland
Librairie Payot S.A., Lausanne et Genève; Buchhandlung und Antiquariat, Heinimann & Co., Kirchgasse 17, 8001 Zurich.

Suriname
VACO nv in Suriname, P.O. Box 1841, Domineenstraat 26/32, Paramaribo.

Sweden
C.E. Fritzes Kungl. Hovbokhandel, Fredsgatan 2, 103 27 Stockholm 16.

Tanzania
Dar es-Salaam Bookshop, P.O. Box 9030, Dar es-Salaam.

Thailand
Suksapan Panit, Mansion 9, Rajadamnern Avenue, Bangkok.

Togo
Librairie du Bon Pasteur, B.P. 1164, Lomé.

Trinidad and Tobago
The Book Shop, 111 Frederick Street, Port of Spain.

Tunisia
Société tunisienne de diffusion, 5, avenue de Carthage, Tunis.

Turkey
Güven Bookstores, Güven Bldg., P.O. Box 145, Müdafaa Cad. 12/5, Kizilay-Ankara; Güven Ari Bookstores, Ankara Cad. No. 45, Cağaloğlu-Istanbul; Güven Bookstore, S.S.K. Konak Tesisleri P-18, Konak-Izmir.

United Kingdom
Her Majesty's Stationery Office, 49 High Holborn, London WC1V 6HB (callers only); P.O. Box 569, London SE1 9 .H (trade and London area mail orders); 13a Castle Street, Edinburgh EH2 3AR; 41 The Hayes, Cardiff CF1 1JW; 80 Chichester Street, Belfast BT1 4JY; Brazennose Street, Manchester M60 8AS; 258 Broad Street, Birmingham B1 2HE; Southey House, Wine Street, Bristol BS1 2BQ.

United States of America
UNIPUB, 345 Park Avenue South, New York, N.Y. 10010; mailing address: P.O. Box 433, Murray Hill Station, New York, N.Y. 10016.

Uruguay
Librería Editorial Juan Angel Peri, Alzaibar 1328, Casilla de Correos 1755, Montevideo.

Venezuela
Blume Distribuidora S.A., Av. Rómulo Gallegos esq. 2a. Avenida, Centro Residencial « Los Almendros », Torre 3, Mezzanina, Ofc. 6, Urbanización Montecristo, Caracas.

Yugoslavia
Jugoslovenska Knjiga, Terazije 27/11, Belgrade; Cankarjeva Zalozba, P.O. Box 201-IV, Ljubljana; Prosveta Terazije 16, P.O. Box 555, 11001 Belgrade.

Other countries
Requests from countries where sales agents have not yet been appointed may be sent to: Distribution and Sales Section, Food and Agriculture Organization of the United Nations, Via delle Terme di Caracalla, 00100 Rome, Italy.

Tipo-lito-fotocomposizione Sagraf - Napoli

P/N1100/E/12.79/1/6000